RADIOLOGICAL MONITORING FOR CIVIL DEFENSE

August 13, 1963

EDGERTON,
GERMESHAUSEN &
GRIER, INC.

SANTA BARBARA LABORATORY

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By: Edgerton, Germeshausen & Grier, Inc.
Santa Barbara Laboratory

Approved by: Henry M. Borella

EDGERTON, GERMESHAUSEN & GRIER, INC.
Las Vegas, Nevada   Boston, Massachusetts
Santa Barbara, California

Abstract

Radiological monitoring and fallout prediction concepts of the present civil defense program are presented and recommendations made for improving the program. The conclusions and recommendations result from a detailed study of the radiological information needs and various radiological monitoring methods. This study included instrumentation and equipment, small scale perturbations of the radiation field by various factors, and fallout prediction methods. The recommendations made include using aerial monitoring techniques as the primary radiological monitoring method and considering the use of a fixed automatic system at the national level only. Other specific recommendations involve instrumentation, training, and organization.

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I. INTRODUCTION

The present civil defense program has been examined from the viewpoint of radiological monitoring and fallout prediction on the state and local levels to make recommendations that will fill existing gaps in, and generally strengthen, the over-all program of civil defense. The purpose of this contract is stated in the scope of work as follows: "The contractor shall examine prediction and monitoring systems on the state and local levels to develop improved collecting, handling, and displaying systems. Consideration shall be given to improved instruments and related equipment, including automatic reporting systems as to the role and adequacy for the task. Particular emphasis shall be given to the evaluation of aerial and mobile monitoring techniques and to improved methodology in obtaining radiological data. The effects of weathering, ground roughness shielding of vegetation and nearby structures and limitations of instruments shall be considered...."

The study began with an analysis of the radiological information needs of a civil defense program. This analysis is described in Chapter III. Prediction and monitoring techniques for use on state and local levels are discussed in Chapters IV and V. Aerial and mobile monitoring techniques were extensively studied. Based on experience and discussions with OCD personnel, a number of basic requirements and an operational plan for aerial monitoring were determined and are described in Chapter IV. Chapter VI contains a description and discussion of the various monitoring and communication instruments and equipment. The effects of weathering, ground roughness,

and shielding by vegetation or nearby structures on the accuracy and reliability of radiological monitoring data are discussed in Chapter VII. The conclusions reached and recommendations made by EG&G, Inc., as a result of this study are presented in Chapter II. These recommendations are intended for application to the present civil defense program and are believed to satisfy the acute needs on a state and local level. In making these recommendations, it is implied that the remainder of the present civil defense radiological monitoring program shall remain unchanged or be altered slightly to permit the inclusion of these recommendations.

While the objectives of this study are limited by contract specifications to fallout predictions and radiation monitoring, the conclusions reached and the recommendations made become meaningful only when they are integrated with a total defense system and related to estimates of the conditions resulting from an enemy attack. A total defense system is not discussed but a brief look at the possible and probable national attack and post-attack situations is essential for a better understanding of the conclusions and recommendations. This understanding is brought about by the consideration of the situations under which radiological monitoring, its hardware, organization, and discipline may be expected to operate. In short, operability is an indispensable element of all parts of the civil defense system.

It must be emphasized that during and following a nuclear attack, the capabilities of these systems may be drastically reduced if not completely destroyed. Under these conditions improvised civil defense capabilities will have to be employed by surviving personnel. The more personnel who are trained to take over the various civil defense operational posts and

perform radiological health physics procedures, the better is the chance for an effective and coordinated civil defense effort. In these circumstances, the advantages of having depots well stocked with provisions required for the functioning of equipment and sustaining of personnel are apparent.

An important facet of the over-all responsibility of civil defense pertains to the gathering of radiological data for assessing the extent and seriousness of the fallout radiation hazard. Such information is necessary to keep the population informed of its situation, to carry out rescue and other emergency operations, and to organize an effective recovery program.

Planned evacuation of large population groups from one location to another is considered unrealistic and is not part of the philosophy of the civil defense program. Because of the lack of shelters some movement or relocation of small groups may be advisable during the recovery period and should be carried out if practicable. During the early fallout period, very limited movement of small groups in rural and semi-populated areas may be carried out but should be attempted only in cases involving extremely high radiation intensities. In this study, the movement or relocation of people should not be construed to mean evacuation of large population groups.

All government levels of civil defense organization and the numerous operational units must work together to obtain the needed radiological information and to effect a beneficial civil defense and recovery program. No matter how highly mechanized or well equipped a civil defense organization might be, unless pre-trained and organized personnel are available to interpret data, assess hazards, and carry out actions, the most highly accurate and detailed information will be of little or no value.

II. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY STATEMENTS

The following conclusions and recommendations concerning the civil defense nuclear fallout prediction and monitoring systems for the state and local levels are submitted by EG&G, Inc.

1. Conclusions

1. Aerial and mobile monitoring have not been used to their full capacity in the operational radiological monitoring program.

2. The remote-probe instruments recently developed by OCD (Type CD V-711 and CD V-717) meet the acute needs of the program.

3. The hand-held portable survey meters contained in the CD V-777 kit are technically and economically appropriate for use in the civil defense program.

4. The present civil defense aerial survey meter, CD V-781, is appropriate for aerial monitoring during the early stages of the recovery period. However, requirements for aerial monitoring during later stages of the recovery period will require a meter with a greater radiation sensitivity.

5. A serious problem of the present radiological program is the lack of trained, competent personnel.

6. Automatic radiological instruments are not feasible for use at the local and state levels.

7. Although radiological data must be available to state and local authorities during the fallout period, the presently planned frequency of obtaining monitoring reports from each station is much greater than is necessary.

8. Radiological information during the fallout period need not be complete or highly accurate. Accuracy within a factor of 2 is sufficient. However, during the recovery period more complete and accurate information is necessary.

9. The present method of fallout prediction is sufficient for civil defense needs and serves a valuable purpose in the program.

2. Recommendations

EG&G, Inc., recommends the following:

1. Aerial monitoring techniques as the primary method of obtaining radiological data during the period following the cessation of major fallout deposition (recovery period). Responsibility of these monitoring systems should be vested in the state.

2. Mobile monitoring techniques as the secondary method of obtaining radiological data during the recovery period.

3. Remote-probe monitors, used at fixed monitoring stations in all law enforcement, fire, and highway maintenance department shelters and public shelters during the period of fallout deposition (fallout period) and as long thereafter as required. Handheld portable survey meters should also be used in these shelters.

4. A recruitment and training program, better implemented to ensure the appropriate level of competence for all civil defense personnel e.g.,

   a. All law enforcement, fire, and highway maintenance department employees to serve as monitors as part of their normally assigned duties;

   b. Consideration to be given to enlisting professional health physicists.

5. Automatic monitor systems to be considered for use only at the national level.

6. Initiation of a program to develop an airborne radiological instrument which meets the requirements of low level monitoring of fringe areas and at later times in the recovery period.

7. Radiation intensity measurements to be made at the fixed stations at predetermined 6-hr intervals during the first 48 hours after the flash report and on a daily basis thereafter.

8. Radio systems as the primary means of communication.

B. DISCUSSION OF CONCLUSIONS AND RECOMMENDATIONS

1. Radiological Monitoring During the Recovery Period

In almost all situations the information required during the recovery period will involve more detail and a more complete geographical coverage than was required during the fallout period. Because of the predictable decay rate, the radiation intensity can be reported less frequently. After the fallout is down a decay law can be applied and intensity levels at a given location can be calculated for future times. The radiation level as a function of location, however, must be more thoroughly examined. Rescue operations, movement of key people and other recovery operations will move individuals into areas that were not monitored originally and which must be measured. In the general case, the locations which will be inhabited must be monitored and the radiological data must be available to the control center. Representative data should be reported to higher echelons of organized civil defense on a daily basis during this time period.

It is recommended that aerial and mobile monitoring techniques be the major monitoring methods used at the beginning of the recovery period which begins with the cessation of actual fallout deposition. The first requirement of the recovery period is to perform a rapid general survey of the areas affected by fallout. A rapid means of performing this task is to employ aerial and mobile monitoring units. Although both types of monitoring are presently employed in the civil defense

system and are considered essential, they are not the primary methods of obtaining the required radiological data. The incorporation of these methods into the over-all monitoring system as the primary methods, will lead to acquiring data more rapidly and from more monitoring points than would otherwise be possible.

The aerial monitoring method should be the primary method used in the recovery period because of its many advantages. These include mobility, flexibility, speed, and a minimal exposure to personnel. Aerial monitoring techniques can be effectively used to acquire a general survey as soon as fallout deposition ceases. An organized operational plan, including availability of aircraft and crews is necessary for an effective aerial monitoring system. The proper combination of plans and techniques will enable civil defense authorities to be informed of the radiological situation more rapidly than by any other method.

The responsibility of aerial systems for local monitoring should be vested in the state. Each state should form aerial monitoring districts on the basis of area and population.

The present civil defense aerial survey meter (CD V-781) is deemed suitable for use in the early stages of the recovery period. However as the recovery phase progresses, the need for better definition of fallout patterns and more detailed information of relatively low radiation intensities will increase. To extend the application of the aerial monitoring capability into these situations, a more sophisticated instrument is needed. It is recommended that an instrument be developed which will meet the following requirements: detection of 10 mR/hr ground dose rate, automatic altitude compensation, and graphic recording of ground dose rate.

Mobile monitoring becomes essential when more detail is required to assess the radiological hazard and should initially be used for measuring dose rates along those roads and other locations where aerial monitoring information is incomplete. Extensive operational plans, pre-assigned vehicles, and established fuel depots are necessary for an effective mobile monitoring system. A mobile unit can monitor possible evacuation routes and can obtain data in locations beyond the limit of the hand-held survey meter monitoring points. Standard civil defense portable survey meters are adequate instrumentation for the mobile units. but communication systems will vary with the intended use. A unit intended for general surveillance will require two-way radio communications, while a unit dispatched from the control center for nearby monitoring may not. Generally, radio communications are advisable. Vehicles for this use can frequently be made available by the local fire or police departments. Additional private vehicles can be commandeered if necessary.

The number of mobile monitoring units necessary will depend on the extent of the area to be monitored and the population density. In populated areas many streets and highways will have to be monitored under a variety of emergency conditions. Mobile monitoring units will also be required in rural communities to provide adequate radiological monitoring of the extensive rural road system. These mobile monitoring units will represent only a small additional cost to the civil defense program since use will be made of existing instrumentation, vehicles, and communications networks.

In addition to aerial and vehicular mobile monitoring techniques, the use of hand-held portable survey meters is essential in the recovery period. After the initial stages of this period, teams consisting of personnel with hand-held survey meters can

monitor specific areas of interest in greater detail. The versatility and portability of these instruments make them indispensable for collecting radiological data.

2. Radiological Monitoring During the Fallout Period

At a given location, the fallout period is that time during which radioactive particulate matter is being deposited on the ground. The start and duration of the fallout period after a bomb burst will vary with the meteorological parameters, the distance and direction of a given location from the burst, and the weapon parameters. In general, fallout from a single burst is completed in a period of from one to 12 hours, for multiple bursts, this time may be extended. The duration of the fallout period will also depend on the location of the observer. At any given location on the West Coast, fallout may be from one or only a few bursts whereas due to the prevailing westerly winds, a location on the East Coast may experience fallout from many bursts extending over a long period of time. The period, therefore, referred to as the fallout period is not an absolute length of time, however, it does connote the early period of the emergency in which early assay of the extent of the emergency is difficult. It is also the period when panic and confusion may result from lack of communications and transportation.

Although detailed information or numerous and frequent radiation intensity measurements are not required during the fallout period, the information that is obtained must be reliable because it is during this period that lives can be saved by correct decisions. This information can be obtained from three types of instrument systems: (1) hand-held survey meter measurements made at predetermined localities, (2) remote-probe instrument measurements reported from shelter areas, and (3) automatic monitoring systems. It is recommended that remote-probe monitors and hand-held survey meters be used on the city

and county levels. The instruments contained in the CD V-777 radiological monitoring kit are appropriate and satisfactory instruments to use. These instruments are the CD V-700, CD V-710 or CD V-715, and CD V-720 or CD V-717 remote. In future kits the CD V-710 will be replaced by the CD V-715 and the CD V-720 will be replaced by the CD V-717 remote.

Fixed monitoring stations utilizing remote-probe instruments and hand-held portable survey meters located in shelters at various locations throughout the community, will be adequate for obtaining the necessary radiological data. It is recommended that the facilities and personnel of various state and local government agencies be used in the fixed station monitoring network. Since only a few monitoring stations are required within each community, the use of law enforcement, fire, and highway maintenance centers will be sufficient. By using shelters at these agency locations advantage can be taken of existing communication systems. Also, RADEF* training can be accomplished within each agency and monitoring duties can be made a part of the regular job assignment.

Remote-probe instruments retain many of the advantages of hand-held instruments and overcome one important disadvantage, namely, that the use of hand-held instruments necessitates the operator's exposure to radiation. A hand-held portable survey meter should be available to measure the radiation level inside the shelter so that the relative radiation exposure of the occupants may be determined.

Generally, an automatic fixed monitoring system, including a control center and alternates and instrumentation for automatic operations, would be too expensive to install and

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*Radiological Defense

maintain on a local level. This fact is apparent when the advantages and disadvantages are weighed against those of the hand-held and remote-probe methods. The slight improvement in speed does not offset the fact that the usefulness of the automatic system decreases as the recovery period progresses. Detailed surveys with hand-held instruments must be made to effect a complete recovery. Because hand-held instruments are essential during the recovery period, the addition of automatic systems on the local level would unnecessarily double the instrumentation and greatly increase the cost of the monitoring system.

The state and national levels will also require information from the local level during this period to formulate initial plans of recovery and assistance. Two methods of obtaining this information are available. Information can be transmitted from local centers or an independent monitoring system can supply the data. It is recommended that both methods be employed for the state and national levels. It is also recommended that consideration be given to automating the independent system at the national level. The data gathered by a federal automatic fixed monitoring system could be transmitted simultaneously to the state centers. Cooperation between state and federal authorities will permit optimizing the positioning of detectors within each state to meet the requirements of both organizations. In utilizing data from this system, the state would have supplementary information to aid in assessing the gross radiation hazard. Examples of federal monitoring systems presently in operation that can be utilized by states or counties are the FAA Weather System at local airports and U. S. Forest Service locations.

The frequency requirement for reporting radiological information depends in general on how rapidly the radiation level

is changing. In the case of a single burst, the radiation intensity during the fallout period will increase to some maximum and subsequently decrease according to a radioactive decay law. During the fallout period, no prediction scheme from the buildup of radiation fields is as accurate as the subsequent decay function. If multiple bursts are considered, fallout from the later bursts may superimpose a buildup on a decaying radiation field. This type of changing radiation field is highly unpredictable. Therefore, the frequency of reporting from any given location required to assess the hazard at that location, should be greater during the fallout period than during the recovery period.

A reasonable routine time between readings from a fixed monitoring station in the early stages of fallout would appear to be about 6 hours and an accuracy within a factor of 2 is sufficient during this time period. The recommended 6-hour period avoids the possibility of swamping the control center and allows time for acting on decisions based on the data. Greater accuracy would not alter any decisions made during this early period.

3. Civil Defense Personnel and Organization

a. Personnel Recruitment and Training

A severe problem of the present civil defense radiological program is the lack of trained and competent personnel. Without such people, civil defense will not function efficiently nor effectively in time of emergency. Even a highly sophisticated monitoring system is useless without competent personnel to interpret the data. Therefore, it is recommended that the program of training civil defense personnel be emphasized to establish the appropriate levels of technical competence.

The qualification requirements for personnel vary with the individual's position in the civil defense program. At the

highest echelon of responsibility, such as the RADEF chief of a national region or a state, the training must be complete. The individuals in these positions must also be leaders, capable of making major decisions in times of great stress. In the national and state offices that have been contacted, it has been found that these positions are filled with responsible, well-qualified personnel.

At the county and city levels, the responsibilities of the RADEF chiefs and their alternates are similar to those at the state level but on an appreciably smaller scale. Some assistance can be expected from the higher echelon offices, but in dealing with local problems the RADEF officer at the county or city level will have the primary responsibility. His training, therefore, must be extensive and he must be well versed in weapons effects. The number of qualified persons needed throughout the nation at this level is about 4,000.* This number assumes one competent person for each of the 3119 counties in the U. S. and one for each of the 740 cities of over 25,000 inhabitants. In sparsely populated areas, one RADEF chief will serve more than one county, while in areas with a high population density more than one RADEF officer per county will be needed. From limited observation it is the opinion of EG&G, Inc., that at present, some of the personnel in these positions are neither as technically competent nor as well trained as these positions require.

Individuals acting as monitors, shelter chiefs, or control room assistants, and those assigned to certain other duties within the local civil defense program must also have an understanding of radiation its hazards and measurements, and should be well acquainted with nuclear weapons effects. Moreover, each person in the civil defense organization should also be capable of directing the general public in decontamination,

*Alternates for these positions have not been considered in determining this figure.

recovery, and emergency operations, as well as of performing his specific task. Refresher courses are necessary to maintain the competence of these personnel; these courses should be given periodically.

The recruitment of qualified personnel presents a formidable problem. A suggestion to assist in overcoming this difficulty has been made by F B. Oleson,[1] RADEF officer in Region I. The suggestion calls for the recruitment, on a voluntary reserve basis, of the 1500 professional health physicists in the U.S. Although these men do not generally enter the civil defense program, they could be of service in time of emergency. Because health physicists understand the elements of radiation protection and the monitoring of radiation fields, they would not require elementary training courses. If these individuals were approached through an appropriate national society and agreed to serve on a reserve basis, they could at least be kept up to date on the civil defense program and be advised as to what they could do in the event of a nuclear attack.

b. Necessity of Pre-Planning, Organizing, and Practice

To carry out a logical civil defense and recovery program even with a highly competent trained civil defense staff, each particular phase of the program must be preplanned, organized, and well equipped. It is obvious that much has to be done by way of obtaining equipment, shelters, provisions, and stockpiles of various items before an attack. Organized plans and exercises, covering as many situations as possible and including alternate plans and methods are necessary for a successful civil defense program.

The plans must provide food, fuel, medical, and other essential supplies for the operational personnel. Consideration

must also be given to the possibility of losing a major percentage of these personnel. In this case, the civil defense program must be implemented and carried out by the survivors.

To permit the necessary exchange of civil defense information, to provide assistance, and to maintain a uniform approach to radiological problems, coordination of the programs must be effected by the state. The reluctance on the part of the public to undertake preparations for civil defense has resulted in weak or non-existent programs in many vicinities. To overcome this lack of interest in civil defense preparations, the need for them must be demonstrated at the state and federal levels.

To develop proficient monitors and staff personnel and to refine the various radiological defense plans, operational exercises should be held periodically. Such exercises have been organized and conducted in the past, but better and more frequent exercises are needed. If personnel can become familiar with a routine in practice they will function much more efficiently in an actual emergency.

4. Communication

The use of existing communication systems in the civil defense program increases the probability of having an adequate communication capability in time of national emergency. Any system can be disabled or destroyed in the event of a nuclear attack. By incorporating all the appropriate existing systems into the civil defense program a greater assurance of having communications exists. Various systems can be used where they are most appropriate and the total communications system would thus become flexible and diversified. Continued use of radio, telephone, state and city police, and fire department networks and the systems of various other agencies is recommended.

5. <u>Fallout Prediction</u>

No essential changes are recommended in the fallout prediction methods utilized in the civil defense program. The present method of plotting danger sector estimates from upper wind fallout (UF) data should be continued and the importance of keeping daily records stressed.

Fallout predictions should not be used as the basis for evacuation of a community or area. The winds are continually changing in time and space; therefore, predictions of the exact locations where fallout will occur are far from precise. If movement were necessary for other reasons, then fallout prediction should be used as a factor in determining the direction of evacuation.

III. RADIOLOGICAL INFORMATION NEEDS FOR A CIVIL DEFENSE PROGRAM

A. INTRODUCTION

Radiological information which describes the radiation field, is needed to provide data at the local level upon which to base decisions. In time of emergency, decisions must be made quickly and those involving radiation hazards cannot be made without radiological information. Questions to be decided may include:

1. Has fallout occurred, and if so is it dangerous?
2. Should people be warned to take shelter?
3. Should people be relocated?
4. Are rescue operations feasible or possible?
5. When can people come out of shelters?
6. When can people resume reasonably normal living conditions?

Another reason for obtaining data is to supply information to the state, region, and other federal agencies. If these agencies receive screened information, they can coordinate the decisions affecting the state and local levels; hence, it is important that the information be transmitted to the higher echelons.

From dose rate measurements and fallout arrival times taken at a given location after one detonation, an estimate of the total dose can be made for that particular fallout field if the time lapse between the detonation and the reading is known. If multiple bursts occur, a decay curve would have to be plotted from several readings at different times to determine the decay rate of the resultant fallout field. The infinite dose can also be estimated.

The radiological data which should be obtained are the dose rate in roentgens per hours at a given location, the unsheltered total dose in roentgens received at that location, and the total dose in roentgens actually received by individuals. Most of these data must be related to the time of the bomb burst, or bursts, to be useful. The dose rate at a given location may be obtained from a fixed-type instrument, manned instrument, survey aircraft, mobile monitor, or remote reading instrument. To obtain reliable data, the location of the detectors and the methods of obtaining the data should be known.

In determining the distance required between monitoring points, two types of effects must be considered, large-scale and small-scale effects. The large-scale effects refer to the radiation intensity pattern from fallout on a level, smooth, hard, infinite plane. The small-scale effects refer to how this pattern is perturbed by local shielding, such as buildings, hills, mountains, by ground roughness, and by the effects of weather elements on the deposition of the fallout.

An examination of the large-scale effects can lead to an understanding of the over-all radiation pattern, but without a detailed description of the local environment, a prediction of the radiation level at any given point must necessarily be an estimate only. This may be understood if the contribution to the dose rate at a point on an infinite plane from evenly distributed fallout is examined. In this case, approximately 35% of the dose rate results from radioactive material at a distance greater than 100 ft. This means that the physical surroundings of an individual play a very important role in determining the dose rate at his location.

Idealized fallout patterns for various wind speeds, presented by Glasstone,[2] indicate that a reasonable maximum

gradient in the radiation intensity which might be expected from large-scale effects only is a factor of 10 in 10 miles. Although downwind gradients are smaller than this, crosswind gradients may be two to three times greater. This factor of 10 in 10 miles is assumed to be a reasonable average, since winds vary in both direction and velocity.

B. USE OF RADIOLOGICAL INFORMATION

1. During the Fallout Period

During the time when fallout may occur, measurements of the radioactivity of an area will indicate whether:

1. Fallout has occurred in that area
2. The radiation intensity is increasing
3. The radiation levels are dangerous
4. Fallout has ceased

The state of the fallout process must be known before decisions can be made. Thus, information received from monitoring stations will help determine whether the fallout is increasing or has stopped and whether a decay law can be applied.

In some instances of high-level radiation fields, it may be necessary to take remedial action during fallout. This action may include moving unsheltered persons to a region of lower radiation intensity. Reliable information from monitoring locations is essential to move these people in the correct direction. It must be remembered that any action taken during the fallout period is likely to be the result of an extreme emergency and any decisions must be partially based on the estimated peak dose rates. The information needed during this period, therefore, must be reliable rather than highly accurate.

It is not feasible to assume that during the early stages of the fallout period a detailed picture of the radiation levels can be obtained. It is desirable, however, to obtain a general concept of the over-all levels and the rate of change of these levels from reliable monitoring stations even though the stations may be widely separated. Many monitoring stations which function well in practice, or at some later time after the emergency, may not be operable during the fallout period. Communication tie-ups and dislocation of operating personnel will contribute to this lack of information.

Radiological information during the fallout period may be used to:

1. Assess the radiation hazards in order to advise the population of the necessary remedial action

2. Assemble information concerning the buildup of the radiation field for transmission to the state level

3. Enable the local officials to advise the industrial and utility concerns properly of the most reasonable action for the best interests of the public and the protection of property

2. <u>During the Recovery Period</u>

Radiological information after fallout is down will be used to aid in the recovery operations. On the local level, information will be necessary from many locations to assess the hazards adequately. With the levels of radiation possible from a nuclear attack, an early consideration will be to save lives from gross radiation exposures. To do this, a report of the radiation levels delineating the hot areas must be available. If such a report is available, safe areas and exclusion areas can be set up and the feasibility of recovery operations can be ascertained. Recovery may involve exposing individuals to large amounts of radiation in the performance of

lifesaving operations, such as evacuating victims of blast or thermal effects. To prevent serious physical damage to a rescuing individual, the levels of radiation and his estimated dose must be determined. Every operation requires a decision as to whether or not the operation is worth the radiation exposure. The more complete and more accurate the dose rate figures, the more reasonable the decisions.

Severe exposures to radiation normally require medical treatment. If the radiation doses to individuals and the levels of radiation existing in a given area are known, certain medical needs of the community can be estimated, and attempts can be made to fill those needs. If the radiation information is not available, this aspect of the problem may prolong the recovery period and may result in more personal discomfort and death than is necessary.

C. INFORMATION REQUIRED DURING THE FALLOUT PERIOD

1. Rural Areas

Radiological information during the fallout period in rural areas must be obtained from monitors located in inhabited areas only; monitoring large areas of uninhabited territory is unnecessary. A rural inhabited center may be a single farm house, ranch or remote dwelling, or it may be a small crossroads community. The distances between these communities may be relatively great, with large areas of uninhabited territory between. If each community is a monitoring point, the distance between monitoring points can easily be 10 miles or greater. Because the large-scale effects of fallout can give rise to a gradient in radiation intensity of a factor of 10 in 10 miles, extrapolation of the radiation levels from nearby locations can give rise

to errors which are unacceptable. It is necessary, therefore, to make radiation measurements at each community. If small-scale effects are superimposed on the average or large-scale effects, the need for local data is more apparent.

2. Medium-Population Density Areas

In areas of medium population density it is generally necessary to have more monitoring points than in rural districts where the population is more thinly distributed. As has been pointed out, the large-scale effects can produce a radiation intensity gradient of a factor of 10 in 10 miles. This figure would make a monitoring point every 3 miles desirable in order to know the large-scale radiation levels within a factor of approximately 2. The actual spacing of monitoring points depends on the population density, the local terrain, and the monitoring system employed. Based on the expected radiation gradient and the average area for a given population, it is the opinion of the authors that there should be at least one fixed monitoring station per 10,000 population, but never less than 3 for any individual community. Detectors may be affected by local, small-scale effects and may give results which are not representative of the over-all pattern of radiation intensities. In using fixed station monitors, a prior determination of the small-scale effects on the detector should be made. If manned instruments are used, an average value of many individual measurements can be made to represent the average intensity of the radiation field.

3. Densely Populated Areas

During the fallout period, no mass movement of people from large cities is practicable. By the very nature of cities, however, more sheltered areas exist and in some cities where the shelter program has been actively pursued, good provisioned shelters exist.

Considering the extensive area of most cities, it is possible that sheltering will be necessary in some sectors but not in others. Because of the increased population density, a fewer number of monitoring stations per population yields the same geographical coverage. Therefore, one fixed monitoring station per 25,000 population in such cities is sufficient. The large number of measurements arriving at the centers from these stations can lead to the assessment of the large-scale effects. However, because of the buildings in large cities, the small-scale effects will be more pronounced than in rural areas.

4. State Level Information

The state civil defense office is a coordinating and advising office and will be required to handle a large amount of data. It is, therefore, necessary for those reporting to the state to reduce the data to give only the average values of the radiation levels prevalent in their areas. The duties of the state office include advising the sub-state regions of the state-wide radiation levels. The state office will be the first echelon which has enough data to produce meaningful state-wide isointensity patterns.

D. INFORMATION REQUIRED DURING THE RECOVERY PERIOD

1. Rural Areas

During the recovery period, a person in a shelter must know when it is safe to come out. As was pointed out in Section III-C-1, in rural areas the data upon which to base these decisions must be acquired locally because the distance between two inhabited communities may be too great to permit extrapolation from data acquired in other areas. Therefore, the information needed to determine whether or not it is safe

to vacate the sheltered area must be obtained from actual radiation intensity measurements in that community.

Remedial action in the form of moving people into a region of lower intensity also demands radiological information from the adjoining communities. This information may not be available in the early stages of the fallout period, but must be made available by the state office as soon as possible.

2. Medium-Population Density Areas

In areas of medium population density the monitoring and decontamination procedures follow much the same pattern as those employed in the rural areas. More people are involved and, hence, more data will be necessary. Two important differences exist: (a) people will not be able to move as easily to adjacent regions, and (b) utilities and industrial organizations will have to be reactivated as soon as possible.

The fact that many people will not be able to move into other regions because of lack of transportation, lack of radiological information, and other factors, means that more detailed monitoring procedures are necessary in the local areas. The monitoring required in this case deals mostly with small-scale effects. Radiation levels in particular areas in a small town may be different from the average level of radiation, and these areas should be located. If radiation intensities are excessively high, they must be identified and the public informed. Areas of low-radiation intensities can provide refuge for some of the population.

Utility companies must maintain the best service possible if recovery is to be effectively and rapidly accomplished. A power station may be able to operate with few or no personnel during the fallout period, but normal maintenance must continue

during the recovery period if the plant is to continue functioning. This is true also of water and gas supply systems. For maintenance to be effected, these facilities must be monitored. Local radiological information must be available for renewed operation of essential industries.

3. Densely Populated Areas

It is not practical to move the population of a large city during the initial stages of the recovery period. As was the case in the small town, more detail of the fallout pattern with respect to the small-scale effects will be necessary for effective recovery operations. Rescue operations, rehabilitation, decontamination, and revitalization of utilities and industry, which are all parts of the recovery program, will require radiological information obtained locally.

The radiation levels of streets and roads will be of particular interest in cities. Streets that are not passable because of local high-level radiation fields must be located. The radiation intensity in the streets also gives some indication of the radiation hazard to be expected in the adjacent buildings. Radiation fields along the rights-of-way of other public transportation systems will also require monitoring. In general, the radiological information necessary in a large city during the recovery period consists of accumulated data leading to (a) knowledge of the radiation intensities for virtually every location that is inhabited, and (b) a detailed picture of the extent of contamination of various vital supplies and areas

4. State Level Information

The radiological information necessary at the state level during the recovery period is that which is indicative of the large-scale effects. Less frequent but more graphically

detailed radiological information is required at this level. The decisions necessary consist of those made to provide assistance to the areas requiring aid. The state office can divert food, medical supplies, and medical personnel to areas most seriously affected. Movement of people in an orderly fashion will be more feasible during the recovery period, and the direction of movement will depend on the advice from the state office.

IV. FALLOUT PREDICTION FOR A CIVIL DEFENSE PROGRAM

A. INTRODUCTION

In the event of a nuclear war, the ensuing radioactive fallout can present serious and widespread radiological hazards to the general population. As soon as a nuclear explosion has occurred, estimates of critical detonation parameters, such as location of ground zero, weapon yield, and height of burst, with appropriate weather information, make possible some estimate or prediction of the expected intensity and distribution of the potential fallout hazard. As distinguished from the prompt effects of a nuclear detonation, fallout radiation does not become an actual hazard until the radioactive material lifted into the atmosphere by the detonation is deposited back onto the surface of the earth.

The time required for a fallout particle to fall back to the earth depends upon the size, weight, and shape of the particle, and the forces, such as wind and gravity, acting upon it. The fallout will be acted upon by the winds at all altitudes from the surface of the earth to the maximum height of the cloud resulting from the detonation. The cloud height, of course, depends upon the yield of the weapon and can be greater than 100,000 ft. As the cloud moves downwind, it gradually deposits fallout particles of decreasing size until only submicron-size particles are left. Particles in this size range do not settle back to earth fast enough to contribute appreciably to this local fallout pattern, but will be diffused, diluted, and mixed with the air in bands around the entire earth. If a nuclear detonation occurs at an altitude above the surface of the earth, so that no dirt and debris are sucked into the radioactive cloud, the condensation of the hot

gases and fission products will produce particles predominantly in the submicron range. Therefore there will be little or no local fallout pattern or hazard resulting from such a burst, because essentially all of these radioactive materials will be spread throughout the entire atmosphere and add to the world-wide fallout. On the other hand, an uncontained underground burst will yield very large-sized debris and primarily will produce extremely localized fallout with very little downwind and world-wide dissemination of the radioactive material.

In time of nuclear war, the world-wide fallout is essentially of no immediate importance. The local fallout patterns, however, are of extreme importance both to the military and civilian population. Downwind from a nuclear burst, the area which will be covered with hazardous amounts of fallout depends upon the weapon design and yield and winds at all altitudes to maximum cloud height as well as on the soil and surface conditions of the earth at the ground zero location. For megaton yield surface detonations, hazardous levels of fallout may extend several hundred miles downwind with a width of 50 or more miles. The radiation intensity will generally decrease with distance from ground zero and will decrease as a function of time after detonation. Therefore, shelters will be required for some interim period of time from hours to weeks after the burst.

B. CIVIL DEFENSE REQUIREMENTS FOR FALLOUT PREDICTION

In an effective program of defense of the civilian population against radiation from fallout, it would be ideal to have detailed and accurate prediction information on the location of fallout and the resulting radiation intensities as a function of time. This situation means having complete, detailed, and accurate input data of all of the parameters which influence

fallout in any way. This would include knowledge of the characteristics of the weapon and its detonation, the type of surface and soil at ground zero, and the weather conditions in space and time for several hours after the burst for all distances from the point of burst up to several hundred miles. This ideal basis for prediction is, of course, never achieved, especially when the enemy has control over many of the variables, including the time and location of the burst as well as the various weapon characteristic parameters.

Fallout calculations can, at best, only approach the accuracy and completeness of the input data. Many assumptions must be made because of the insufficient experimental and theoretical data on particle size distribution, fall speeds, cloud shape and size, and particle distribution in the cloud. This reduces the over-all accuracy of any fallout model to the extent that it is useful only in predicting where to expect fallout rather than any indicated radiation intensity as a function of geographical location. After the direction of an expected fallout pattern has been predicted, unexpected changes in the wind structure as a function of time for several hours after the burst can shift the pattern radically. Even under the ideal conditions of weapons tests, unpredictable changes of wind direction and speed have caused actual fallout patterns to shift from the predicted direction. Also, because of fractionation of fission products with particle size and material, as well as terrain and weather effects, the actual fallout pattern will be very irregular.

The requirements of fallout prediction information should be analyzed in terms of the decisions to be made and actions to be taken on the basis of the information received. Fallout prediction data can serve as an early indication of the probability of an individual community being hit by fallout and give

some indication of how much time might be available to reach shelter. Fallout prediction data can serve as a useful guide for a competent RADEF chief in interpreting early monitoring data. Because of the uncertainty of the fallout prediction data, they should not be used as a basis for relocating people. Therefore, prediction information for use by civil defense organizations would consist of a "best estimate" of expected fallout direction, or quadrant sector, from the burst point and a first approximation of the expected time of arrival.

C. METHOD OF FALLOUT PREDICTION

A number of fallout models have been developed for weapons testing operations and military applications. Where there is a sufficient amount of detailed input data, relatively accurate predictions could be made of the fallout pattern and intensities of radiation. In many cases the fallout prediction models have been developed for particular applications. For instance, one model may be based on low-kiloton range detonations for determining only the direction from ground zero of expected fallout. This model would hardly be applicable for predicting detailed dose rate intensity contours from megaton range bomb bursts. Some prediction systems have been devised solely for use long before an enemy attack to give guidance to long-range defense planning. Depending upon the sophistication and completeness of detailed radiation field information produced by the fallout model, the various prediction systems that have been developed are generally one of three types: (a) detailed pattern prediction systems, (b) idealized pattern prediction systems, and (c) danger sector prediction systems.

1. Detailed Pattern Prediction Systems

The ultimate in fallout prediction would be the accurate prediction of radiation intensities at all locations and for

any time of interest. The more sophisticated a system, or the more detailed and complete the predicted information, the greater the necessity of having a thorough understanding of all parameters which influence fallout and possession of complete, accurate input data. In spite of the effort expended studying the physics of fallout phenomena, many questions remain about the role, relative importance, and mechanics involved with each parameter which affects fallout. For complete detailed information the fallout model must include information on (a) weapon characteristics, such as total yield, fission yield, and bomb composition, (b) detonation parameters, including height of burst, location of ground zero, and soil type and composition at ground zero, (c) atmospheric parameters which include winds at all altitudes in space and time of interest and diffusion coefficients, and (d) the physics and mechanics of the fallout process.

A number of systems have been devised for detailed radiation intensity contour predictions. However, most of these systems have been devised for specific applications where many of the parameters affecting fallout have been either controlled or made very nearly ideal. Significant differences in results of these various models have always existed because of the differences in assumptions made in developing the models. Some of these different assumptions are made because of differences in the intended application of the systems.

2. Idealized Pattern Prediction Systems

An idealized fallout pattern prediction system is based upon the fallout patterns measured during the various weapons testing series. A detailed knowledge of the physics and mechanics of fallout is not necessarily required. The various fallout patterns that have been measured are scaled with weapon

yield and wind structure. The scaling laws are derived experimentally on the basis of measured fallout data or on a combination of experimentally measured patterns and a knowledge of fallout physics and mechanics. In any case, the prediction system starts with a simple, "idealized" pattern which is then scaled according to weapon yield and wind structure.

The paucity of good detailed experimental data on radiation intensity contour patterns is the basic limitation of these methods. Most of the weapons testing data have been obtained either from low kiloton range detonations in Nevada or from higher yield devices in the Pacific where detailed fallout pattern measurements are extremely difficult to perform.

3. <u>Danger Sector Prediction Systems</u>

The danger sector prediction system of fallout analysis simply consists of making predictions of the quadrant sector where fallout will occur and the time of its arrival at any location. This approach eliminates the need for almost all weapon and detonation parameters except for yield and location of the burst point. Most other weapon and detonation parameters are of the utmost importance in predicting the amount of fallout or the radiation intensity to be expected but are not involved in determining the direction from ground zero where fallout will occur nor the time required for fallout to reach a given location.

This system is primarily based upon the wind structure throughout the space and time of interest. The wind vectors for all altitudes can be drawn and the danger sector defined as that area enclosed by an extension of the azimuthal angles of these vectors in either direction. The time-of-arrival estimate is based on the wind velocities involved. All systems of fallout prediction have the inherent limitation

of inaccuracies of wind structure information. When the only information required is the location and arrival time of fallout, this system may be sufficiently accurate and is relatively fast and simple to use.

D. SPECIFIC FALLOUT MODELS

Many specific fallout models have been devised by numerous groups and organizations for various applications. It is beyond the scope of this report to describe in detail all models which have been devised throughout the past decade or more. In January, 1955 the Armed Forces Special Weapons Project (AFSWP), now the Defense Atomic Support Agency (DASA), held a symposium on radioactive fallout wherein various organizations were invited to discuss their fallout models. In September, 1962, another symposium was held in San Francisco, California by DASA and the U. S. Naval Radiological Defense Laboratory (USNRDL). The major fallout models discussed at these scientific meetings were the USNRDL dynamic model, the RAND model, U. S. Weather Bureau model, and a model being used by the Lawrence Radiation Laboratory (LRL). Each of these models is briefly described.

1. USNRDL Dynamic Model

The dynamic model applies to yields from 0.1 KT to 10 MT for land surface bursts and was designed primarily for scientific studies. It has been applied in designing weapons test experiments, in studies of naval nuclear warfare, and is also proposed as being an operationally useful prediction system. The model is intended to yield information of dose rate contours and fallout arrival time and location. Some of the scientific studies for which it was designed are particle size distribution and particle fall rate studies.

In the design of this model, the early-time dynamics of the atomic cloud have been considered, using a theory for close-in fallout intended to be applicable for all nuclear weapon yields. An attempt was made to take into account the motion of the fallout particles from their inception in the fireball until they finally return to the ground. By taking these early-time dynamics into consideration a more accurate picture of the quantity of fallout, or dose rate intensities, should be obtained.

2. The RAND Simplified Fallout Model

The RAND model was developed to provide fallout hazard estimates for use in long-range military defense planning. This model is primarily intended for use before nuclear war occurs, in predicting the areas affected by fallout and how much fallout would be deposited. The specific information yielded by the model is the time of arrival of fallout at a given location and the fraction of total fallout deposited at that point. The model is for land surface bursts only and early-time cloud and stem dynamics were not considered. Assumptions are made on the particle distribution within the cloud and on the shape and size of the cloud, which is scaled as a function of weapon yield; wind shear was not considered. The model was designed for planning rather than operational use.

3. U. S. Weather Bureau Fallout Prediction Model

The U. S. Weather Bureau model was developed for use with weapons of any yield and under any detonation conditions, to predict where fallout will occur and how much will be deposited. The model can be used for predictions of time of arrival and location of fallout without involving deposition quantity predictions. This application of the model minimizes

the importance of assumptions about the weapon and burst characterisitics and of the physics of fallout, and thereby makes the wind structure data the limiting factor of the prediction method. The incorporation of space and time changes in the winds has been accomplished on a research basis but requires too much input data and computation time to be done operationally. In time of nuclear war, wind structure would not be known in sufficient detail to permit fallout computations as a detailed function of time and space.

4. Lawrence Radiation Laboratory Fallout Model

The Lawrence Radiation Laboratory model was designed specifically for test operation use, and all technical and meteorological information that can be made available under controlled field test experiments has been used. The predictions are then used by test planners as being applicable to safety and some technical evaluation problems. The system yields information of dose rate intensity as a function of time and location. Early cloud and stem dynamics are not considered.

E. CIVIL DEFENSE AND U. S. WEATHER BUREAU FALLOUT PREDICTION METHOD

The method of fallout prediction used by the operational civil defense program consists of making danger sector predictions of where fallout is expected and its estimated arrival time. These predictions, known as fallout area forecast plots, are based upon wind data collected and reported by the U. S. Weather Bureau. The wind analysis is made by balloon soundings up to 80,000 ft by approxmately 80 observatories in the U. S., Puerto Rico, Panama Canal Zone, and southern Canada.

These observatories prepare upper wind fallout vector reports (UF messages) two or four times daily and make them available

to federal, state, and local governments for civil defense. The program makes available current and special fallout wind vector reports in a civil defense emergency.

The wind data are put in the form of five average wind vectors for various altitude intervals up to a height of 80,000 ft. The vectors indicate direction of the wind and the distance fallout particulate matter would be carried in 3 hours. The wind vectors for all altitudes can be drawn and the danger sector defined as the area enclosed by an extension of these vectors in either direction. This extension is accomplished by drawing 20-mile radius circles at the 3-hour distance for the vectors above 40,000-ft altitude and 10-mile radius circles for those below. The danger sector is then defined as that area enclosed by an envelope including these circles as well as the vector lines. The plots can be carried out for a 12-hour arrival distance.

Fallout area forecast plots can be made by community civil defense personnel on the basis of reports of all observatories within 200 or 300 miles of the community. By keeping a log of these plots over long periods of time (years) a probability factor can be established of wind direction and speed. Plots of this type are available for some locations in the United States as a result of a five-year study reported in OCD Bulletins TB-11-31 and TB-11-21.

Danger sector estimates do not indicate the intensity of fallout or levels of radiation to be expected. These estimates are intended to give the various communities some idea about the probability of their receiving fallout and some estimate of time before fallout arrival. On the basis of this time estimate, some last minute preparation for the possible radiation hazard can be accomplished.

V. RADIOLOGICAL MONITORING METHODS

A. AERIAL MONITORING METHODS

1. Background Concepts

a. Introduction

The application of aerial techniques to the study of ground contamination has been actively investigated since 1952. The aerial study of fallout has concentrated on two general categories - close-in monitoring of high-intensity radiation by military and civil defense groups, and the surveying of entire fallout patterns with the objective of delineating areas with dose rates as low as 1 mr/hr. Civil defense groups have investigated monitoring equipment and techniques since Operation Teapot in 1955. During the same test series, aerial surveys of large areas were proved to be effective in determining the pattern of fallout deposited on the ground, and since that time these surveys have been used in most of the major nuclear tests at the Nevada Test Site (NTS). The present status of aerial monitoring techniques is based on studies in both categories.

A complete aerial monitoring capability for civil defense use would consist of two types of systems: a sophisticated system in a high-performance aircraft, for use at the national level and a simple system in a light aircraft for use at the state and local levels. An early operational study was performed at NTS during Operation Plumbbob[3] with a simple system consisting of a CD V-710 survey meter and a light plane. The sophisticated system is the subject of a feasibility study by General Dynamics "Aerial Monitoring System Study,"[4] and will not be considered in this report.

b. Advantages

Some of the major advantages of aerial monitoring may be summarized as follows:

1. Mobility. Although all aircraft require ground support and landing facilities, once the aircraft is airborne it becomes independent of ground support for the duration of its mission. Moreover, the aircraft need not return to the same base. Radiological data and associated geographic position data can be obtained in an area of interest regardless of the conditions on the surface of the earth.

   Aerial systems can be moved hundreds of miles in a matter of hours if the situation in another area requires additional systems. This capability for redeploying systems will permit ascertaining the fallout situation in areas where the local aerial systems have been destroyed or the crews are not able to leave shelters because of high-intensity radiation.

2. Flexibility. Aerial monitoring systems can perform a variety of tasks. Typical missions might include: reconnaissance of large areas to determine the general radiological situation, detailed surveying of hot spots, monitoring a specific road or access route to vital facilities, and even block-by-block monitoring of residential areas. In addition to these radiological activities, the aerial missions will yield valuable information on the general situation in the area. After an initial reconnaissance mission, which will determine the general radiological situation, the aerial system can be used to obtain detailed information in critical areas.

3. Speed. Depending on the type of light aircraft, surveying can be conducted at speeds of 120 to 200 miles per hour. Within reasonable time limits, 500 to more than 1000 miles can be flown in a single mission. In addition to the speed of surveying, data can be rapidly transmitted by radio as soon as they are obtained if the situation warrants.

4. Simplicity of operation. The operation consists of flying to given locations and measuring the dose rate. A minimal training program would be required to produce adequate monitoring personnel from average private pilots.

5. Availability of aircraft. Since almost any 2-place or larger light aircraft can be used for aerial monitoring, availability of vehicles is not a problem. Several suitable aircraft are based at most airports.

6. Availability of crews. Since an average private pilot with a few hours of specialized training can do effective radiological monitoring there is a widespread and large potential manpower reservoir for aerial monitoring systems.

7. Minimum exposure to personnel. Aerial monitoring crews at 500 ft above the ground receive about one-tenth the radiation dose rate a ground monitoring crew would receive in the same area. In addition to traversing high-intensity areas more rapidly than ground monitors, aerial monitors can reduce the dose rate in the cockpit by increasing the monitoring altitude. Areas that could not be monitored by ground personnel can be monitored by aerial crews without exposure to dangerous levels of radiation.

8. Economy. Except for training, the aircraft and crews are not needed until after an attack. The radiation detection instrumentation and any peripheral equipment or materials are the only special items that must be assembled and maintained in a constant readiness condition. Because relatively large areas can be covered by one aerial system, a monitoring capability for a given area requires fewer aerial monitoring systems than other type systems.

c. Disadvantages

The disadvantages of aerial monitoring systems are:

1. Limitations in aircraft operation. The aircraft is susceptible to blast and thermal effects during the attack period and to excessive contamination by fallout. Because of fallout in some areas crews will not be able to reach their airport for several days

and the local monitoring responsibilities will have to be assumed by neighboring aerial groups. Aerial monitoring of this type can be conducted only during daylight hours and in good to moderate weather.

2. Limitations in the technique. Relatively clean air is required for aerial monitoring data to be meaningful. Radioactive clouds must be avoided if data labeled "ground data" are to have meaning. Small amounts of airborne fission products hamper but do not preclude aerial operations. A relatively large area is "seen" by the detector at 500 feet above the ground. Aerial techniques cannot adequately monitor small, high-intensity areas caused by excessive deposition of fallout such as might occur in the lee of a building. Similarly aerial monitoring systems have little application in monitoring downtown areas in large cities.

d. Summary

The many advantages of the aerial monitoring technique indicated that it should be the primary monitoring method during the recovery period. The only serious limitation on aircraft operation is the requirement for flying weather. Small amounts of airborne fission products can be recognized by trained crews and their effect avoided by operational procedures. The small-high-intensity areas that an aerial system cannot define would be the responsibility of ground mobile monitors. In special situations, however, hot spots can be monitored by flying 100 ft above the ground.

2. Aerial Monitoring System for Local Use

In its most rudimentary form an effective aerial monitoring system for local civil defense consists of a light plane, a field survey meter capable of detecting changes of 10 mr/hr, a graph showing attenuation of dose rate with altitude, a pilot, and a road map. Additional features such as a tape recorder, graphic recorder for radiation data, a more sophisticated detector incorporating automatic altitude compensation, better maps, and a second crewman would increase the

quality of the data, ease of operation, and usefulness of the aerial capability. To a large extent, the amount of equipment and degree of sophistication will be determined by economics.

a. Instrumentation

In formulating the design criteria for aerial monitoring instrumentation, types of detector, recording instrumentation, and dose rate indicators must be considered. A unit suitable for light aircraft must be rugged, compact, light weight, and portable. It must be operationally simple, designed for maximum reliability, and equipped with a small stock of spare parts. A self-contained battery pack is essential, but the unit should also be capable of receiving its power from the aircraft cigarette lighter socket.

A standard, sensitive, field survey instrument (0 to 2 r/hr to 0 to 10 r/hr range) such as the CD V-710 should be considered as part of the aerial monitoring system. This unit could be used in an emergency as an indicator of cockpit dose rate if the primary instrumentation failed. A tape recorder is also standard equipment because as a survey progresses it will be used to record a running commentary on radiation intensities, blast and fire damage, trafficability of roads, etc.

The radiation detector should be capable of measuring the ground dose rates without exposure of the flight crew to excessive amounts of radiation. The simple expedient of flying higher permits extremely high-intensity areas to be monitored. The upper limit of the radiation detector, therefore, can be determined on the basis of an acceptable dose to the crew. A practical upper dose rate limit is 10 r/hr. Extensive aerial radiological surveying by United States, Canadian, British, and Russian groups indicates that about 500 ft above

the ground represents the best compromise between flight safety and quality of radiological data. Since the dose rate at this altitude is about one-tenth the dose rate on the ground, the lower limit of the radiation detector should be one-tenth the minimum ground dose rate to be detected. During the first few days of the post-attack period the ability to detect 100 mr/hr ground dose rate is acceptable but the use of the aerial system will not be feasible in the later days of the recovery period unless the lower limit is 10 mr/hr ground dose rate. This means the lower limit of detectability of the aerial instrumentation should be 1 mr/hr.

Since the airborne radiation detector measures the radiation at the detector, the aerial data must be converted to ground dose rate data. This compensation for altitude can be accomplished in the instrumentation so that ground dose rate data are displayed. Without automatic compensation the cockpit dose rate must be corrected manually. Automatic compensation increases the complexity and cost of the instrumentation but it significantly reduces the task of data reduction.

The radiological data must be displayed for the crew. This can be done with a meter or digital display. While not essential, graphic recording of the data is desirable because it permits a more detailed examination of the data after completion of a mission.

The CD V-781[5,6] is the present civil defense aerial survey meter. It consists of three units: a meter and signal unit, detector unit, and simulator unit. A tape recorder is included as an accessory. The system consists of three separate Geiger-Mueller (G-M) tube detectors and dose rate meters covering the ranges 0 to 0.1 r/hr, 0 to 1 r/hr, and 0 to 10 r/hr. Three meters for indicating the measured, or cockpit, dose rate are included in the meter and signal unit. It is

designed to be mounted on the cowl of a light aircraft, directly above the instrument panel. Either the aircraft power supply or an internal battery pack (eight standard "D" cells) furnish power for the system. The simulator unit replaces the detector unit in training exercises so an instructor can insert simulated dose rates in the meter and signal unit.

CD V-781 represents an answer to the problem of radiation monitoring and has been partially field-tested at the Nevada Test Site. It has been designed for economy, reliability, and simplicity.

The lower limit of radiation detection of the CD V-781 limits its usefulness in surveying fringe areas of fallout patterns in the early post-attack period and most of the patterns in the later periods of recovery. As the recovery phase progresses, the need for better definition of fallout patterns and more detailed information of relatively low radiation intensities will increase. To extend the application of the aerial monitoring capability into these situations a more sophisticated instrument is needed. This system is not included in the present civil defense inventory. Since this system would be employed after the radiological situation had been assessed by the CD V-781 systems, the location of the fallout patterns would be known and fewer systems would be required.

To obtain meaningful radiological data during the later stages of the recovery phase it is recommended that a program be initiated to develop an airborne instrument which meets the following requirements: detection of 10 mr/hr ground dose rate, automatic altitude compensation, and graphic recording of ground dose rates.

b. Aircraft

The vehicle for the local aerial monitoring system can be any two-place, or larger light aircraft. A 4- to 6-place aircraft, such as the Beech 33 and 35, the Cessna series 172 to 210, and the Piper 24 and 28, is preferable because of greater range, speed, and maneuverability. Standard aircraft radio communication equipment is desirable but not absolutely necessary. Because of the widespread distribution of this type aircraft in the United States, availability of aircraft will not be a problem.

c. Crew

The aerial monitoring system for local use can be operated by a one-man crew. Several factors, however, indicate that a two-man crew would be preferable. Although monitoring operations are relatively simple, they require more attention to flight altitude, flight path, and reading of instruments than does normal flying. Many pilots taking part in post-attack operations may be relatively inexperienced in aerial monitoring techniques and all pilots will be under severe tension. A two-man crew will permit one man to concentrate on flying while the other man concentrates on the purpose of the mission, i.e., to obtain radiological data and associated geographic position. The observer will be able to keep track of the flight path and radiological situation and thereby recognize inconsistencies in the data. The observer can enter radiation intensity values on the flight map as the survey progresses so that immediate data are available as soon as the mission is completed. More time would be available for recording special or unusual features than would be possible with a one-man crew. For these reasons and since the speed and range of the aircraft are not affected by his presence, a second crewman is desirable.

d. Maps

Although effective surveying along roads can be accomplished with road maps, the 1/250,000 scale series (4 miles equal 1 inch) topographic maps of the United States, published by the Army Map Service and U. S. Geological Survey, is recommended for general use. Each map covers 1 degree of latitude and 2 degrees of longitude. It requires about 450 of these maps to make up a conterminous U. S. map. Larger scale topographic maps (1/62,500 and 1/24,000 scale, approximately 1 inch equals 1 mile and 2-1/2 inches equal 1 mile, respectively) are available for many parts of the country. Planimetric county road maps of scales of 1 inch equals 1 mile and 1 inch equals 2 miles are published by each state highway department and are excellent maps for detailed road traverses. Several copies of all available maps in a 50-mile area around the local unit should be stockpiled for emergency use. Use of the large-scale maps will make possible a positioning error of less than 1/2 mile. Road maps of several districts surrounding the home district should be ready in case systems must be redeployed several hundred miles.

e. Number of systems

The area of responsibility for a single aerial monitoring system should be smaller for densely populated areas than for rural districts. The average survey area should be about 1500 square miles which permits a reasonably detailed survey of the area to be completed in 3 to 4 hours. On this basis, the approximate number of aerial monitoring systems for local civil defense use in the conterminous United States would be 2000. At least 4000 systems should be procured to allow for system failures and for redeployment.

3. Organization

a. Controlling Unit

The purpose of the aerial monitoring system described in this report is to acquire radiological data for civil defense organizations below the state level. From a strictly organizational standpoint the local units should have control of the aerial systems that will be obtaining data for them. If the capabilities and the most effective employment of the aerial systems are considered, however, control should be exercised by larger groups, such as state or sub-state units. As stated earlier, the mobility, flexibility, and speed of aircraft operation permits each system to monitor an average of 1500 square miles. Since many cities, and even some counties are much smaller than this and in the major urban areas cities adjoin, apportionment on the basis of local units will not permit efficient use of aerial systems. The maintenance of equipment and the training of flight crews and control center personnel are facilitated by having several systems in an operational unit or district. Centralization of control will also expedite redeployment of aerial systems. If control of the aerial systems were vested in city and county civil defense units, they might be reluctant to part with their aerial systems until their area had been checked in detail. State control, however, would permit allocation of systems on the basis of need.

It is recommended that the responsibility of aerial monitoring be retained by the state. Each state should form aerial survey districts, consisting of 3 to 8 aerial survey areas. The basis for selection of districts should be area, terrain, population, and airports. The number of aerial systems in each district should be double the number of survey areas to allow for system failures and redeployment.

b. Control Center

The control center for the aerial monitoring systems of an aerial survey district should be at an airport with radio communications. There are many possibilities for the organizational responsibility of the aerial capability: Civil Air Patrol (CAP) units; Federal Aviation Agency Flight Service Stations (FAA-FSS) control towers or communications units; flying clubs, fixed-base operators; or the airport administrative personnel. The CAP units, because they have an organization and interested volunteer pilots and are presently involved in civil defense work, and the FAA-FSS, because of their daily experience and almost constant contact with pilots in their areas, should receive first consideration. However the situation in each district will probably be different. The primary considerations are to have interested personnel and an effective organization. The close coordination between the aerial survey district control center and all local civil defense units in the district will be necessary.

The special equipment requirements of the control center are few, since existing airport radio and other facilities will be available in case of an emergency. Radiation detection instruments, spare components, and adequate maps are of major importance and should be stored at the command post. Adequate drafting equipment, and paper and film for preparation of overlays, will also be needed. After the fallout period, aerial survey missions can begin as soon as crews are able to make their way to the airport and receive their instructions.

4. Operations

a. Post-Attack Operations

Following a nuclear attack, the initial requirement of any civil defense organization will be to assess the situation in its area of responsibility. Aerial monitoring, because

of its mobility, will play a major role in this initial assessment. Although guidelines, suggested utilization, and consultation on plans should be furnished in advance, the successful employment of the capability in an emergency will depend on the local situation and the ability and imagination of the individual users.

Responsibility for aerial operations in each district should rest with the chief controller, who is a member of the state civil defense organization. He will work closely with the county and city civil defense units in his district to determine surveying priorities. Requests for additional aerial monitoring systems will be made to state headquarters. State headquarters also will be notified about the existence of systems not in use. In the event a district control center is incapacitated, state headquarters will direct adjoining districts to assess the radiological situation in that district. The extreme mobility of the aerial survey capability permits operational systems to be moved many hundred miles within a few hours.

The spacing of the traverses on the initial mission should be such that the entire area would be covered during a 3 to 4 hour flight. Factors to be considered in determining the spacing of traverses would include the range and speed of aircraft available, the size of the area, the distribution of population in the area, and a preliminary estimate of the radiological situation in the area. The initial mission should determine:

1. General radiation levels
2. Location of hot lines
3. Amount of blast and thermal damage
4. Trafficability of roads

This aerial reconnaissance may well produce the first comprehensive picture of the damage in the area. Information obtained on the initial mission would guide the planning of successive missions. Aerial surveys, even with standard sensitive field instruments, can continue to acquire valuable radiological data until the ground level dose rate is well below 100 mr/hr.

Initial preliminary information on the radiological situation and any other pertinent items will be transmitted immediately to affected county or city civil defense units. The crew will then reduce their data using the flight maps and tape recording. Since the time of readings are recorded on the flight maps the observed dose rates can be corrected to a common reference time and then entered on a master map at the control center.

b. <u>Training</u>

A brief but complete course should be prepared at state or higher level because specialized knowledge and training materials are required. Specific subjects to be covered include typical and atypical fallout patterns, effect of topography on fallout patterns, surveying techniques, attenuation of dose rate with altitude (barometric altitude and ground-to-detector distance), and recognition of fallout in the air while surveying.

All crew members should receive as many training flights as possible using special training aids, such as the CD V-781 aerial survey meter simulator. Although part of the flight time profitably can be group work, each pilot needs several hours operating experience as pilot or observer. Compiling data on a situation map is an important part of the training program for crews. Assembling raw data and preparing a

coherent picture of the radiological situation in the local area will develop a better understanding of the quantity and quality of data that are needed.

B. SURFACE MOBILE MONITORING TECHNIQUES

1. General Use and Evaluation

The concept of mobile monitoring consists of transporting a radiation instrument in, or on, a vehicle to enable a larger area or number of locations to be monitored in a short time. In most cases, mobile monitoring is an extension, or particular use, of the hand-held portable survey meter technique. The vehicle enables the monitor to cover a greater territory or a greater number of stations in shorter time.

Extensive mobile monitoring would not be applicable in high-level radiation areas because most light vehicles offer only a protection factor of 2 or less. Consequently, the major use of mobile monitoring is during the recovery phase. Mobile monitoring is utilized to obtain a greater detail of the fallout field than is obtainable from the fixed monitoring system or from aerial monitoring.

Mobile monitoring teams should consist of at least two people, a driver and a monitor. Choice of instruments with appropriate readout and fast response times is important. Radiation intensity inside the vehicle can change rapidly at high speeds. If a radio is available in the vehicle, reporting can be done as readings are taken. The readings and appropriate information should be recorded in writing by the person doing the monitoring. Mobile monitoring units should be based on well-organized groups, such as police, firefighters, and highway maintenance crews, and thereby capitalize on existing vehicles and communication networks. Mobile monitoring can be done without the use of radio communications if

necessary. Readings can be made on a mission, and reported after the mission is accomplished. Such a method is most applicable during the recovery phase.

Many aspects of accuracy, dependability, and reliability pertaining to the hand-held portable survey meter method of monitoring also apply to mobile monitoring. Readings taken inside vehicles, however, will generally be lower than readings taken in the standard manner outside the vehicle. The difference is generally less than a factor of 2 for most light vehicles, such as cars, jeeps, and pickup trucks.[7] Even if heavy trucks were used, the maximum difference would not be more than a factor of 3. Readings of survey meters in vehicles should always be made at the same relative position within the vehicle. Readings in a highly contaminated vehicle might be misleading if the outside radiation level were low. If the vehicle has traveled over highly contaminated areas, the contribution of contamination on the vehicle itself must be estimated before measurements are attempted in low radiation areas. The contribution is expected to be small, however, unless the vehicle has traveled extensively through radiation levels 10 to 100 times higher than those existing at the desired monitoring areas. Vehicles do not, in general, become highly contaminated by traveling through contaminated areas, but will become contaminated if out in the open while fallout is coming down. The use of existing vehicles and communication networks of civil agencies does not represent a capital investment to the civil defense program. However, sufficient fuel for vehicles should be stored in appropriate places for use when needed.

One important limitation of mobile monitoring will be imposed by radiation exposure of survey teams. Even a short mobile monitoring mission will require several minutes to perform. Proposed routes to be surveyed may be blocked by other vehicles or debris, and a much longer time than anticipated may be necessary to complete the task.

2. Use During the Fallout Period

In general, mobile monitoring will not be applicable during the fallout period. The nature and concept of mobile monitoring implies the beginning of some form of recovery.

3. Use During the Recovery Period

During the recovery period mobile monitoring will be essential to determine the magnitude and extent of the radiation hazard in a community, city, or state. Large-scale fallout patterns must be determined in as much detail as possible. Mobile monitoring will provide a means of obtaining necessary data as a supplement to aerial monitoring. If aerial monitoring is not available, mobile monitoring becomes the essential technique for obtaining data necessary to complete the total fallout picture. After large-scale fallout patterns have been determined, mobile monitoring will be primarily concerned with determining the small-scale effects, hot and cold spots, radiation levels along supply routes, and evacuation routes.

a. Rural Areas

Mobile monitoring will be extremely useful in rural areas during the recovery phase. Because of the lack of communication and distance between monitoring stations, the gross fallout picture will probably be quite incomplete for rural areas. Mobile monitoring should be used in conjunction with aerial monitoring to determine the extent of fallout contours.

Areas free from contamination, or having low radiation levels, should be discovered early to allow any necessary remedial movement of the inhabitants of one rural community to another, or people from a semi-populated area to a rural community. It may even be desirable to move people to uninhabited areas. Any such movement will require mobile monitoring units.

b. Medium Population-Density Areas

Mobile monitoring will be more extensive in areas of medium population density than in rural areas because of the existence of more roads, highways, and thoroughfares. During the fallout and shelter period, there will be large areas from which no report or information is available in the central control center. As soon as operationally feasible during the recovery phase, these areas should be investigated, probably by mobile monitoring teams, as a step toward completing over-all fallout contours.

Routes tc vital industries, supply depots, and hospital facilities should be monitored as soon as possible. As recovery progresses, all major highways and thoroughfares must also be monitored.

c. Densely Populated Areas

Most of the principles and problems associated with mobile monitoring in semi-populated areas apply to densely populated centers. However, there will be a greater need for more detailed radiation information because of the existence of more people. Because of the greater population density, the requirements for rescue and recovery operations will also be greater. In these and all outdoor operations, the use of mobile monitoring units will be very important. This use of mobile monitoring units can be greatly complicated by blast and thermal damage in densely populated areas.

C. REMOTE-PROBE AND AUTOMATIC MONITORING SYSTEMS

Remote-probe monitors are survey meters that consist of a detector on a long cable which is connected to the main amplifier. The amplifier and readout make up the chassis which may be a hand-held, rack-mounted, or bench-type unit.

Some remote monitors consist of portable survey meters with an extension cable connecting the detector to the meter. Other examples of these monitors are those employed in industrial sites, which are multichannel-type instruments with many detectors, a rack-mounted amplifier, and readout section.

Automatic systems generally consist of an array of detectors connected by cables, line, or radio to a main control center. An automatic system is like a multichannel remote indicating monitor, except that the distance between detector and readout is generally greater. Since the automatic system could technically be called a remote monitoring system, these two systems will be treated in much the same manner. In general, the remote-probe monitors consist of shorter range systems with a manual readout mode requiring personnel. An automatic system, on the other hand, may not necessarily require hard-wire connections but may utilize a radio telemetry system and also possess the capability of an automatic data handling control center. Therefore, the automatic system is generally intended for use over greater distances with a minimum requirement of personnel.

Remote probe monitors are primarily applicable to the measurements of high-intensity radiation fields. Measurements of these fields are necessary at short times after the arrival of fallout to determine or predict accurately the eventual recovery time. Since it is not desirable to expose personnel to high levels of radiation, a remote indicating monitor with high-level capability is necessary. A remote-probe monitor with a cable varying in length up to hundreds of feet between the detector and readout can be used in a shelter with the probe detector stationed outside and the readout and associated electronics situated inside the shelter. Remote-probe instruments can also be utilized in mobile and aerial monitoring systems if no other instruments are available.

Inasmuch as shelters will be utilized in all areas, remote probes will be directly applicable for use during the fallout period and for as long as the radiation intensities remain high. By use of remote-probe instruments in shelters, the occupants are kept informed of the outside radiation intensity without the necessity of leaving the shelter to obtain a reading. The shelter group can function without an outside authority if a responsible operator with RADEF knowledge is present in the shelter.

In employing a remote-probe monitoring system, the operator must be able to communicate with his control center to report the readings. Since the readout on this instrument is a meter, it must be read and recorded by a monitor who will then relay this information to the proper points. The same problem of communication exists with use of remote-probe monitoring as with the hand-held portable survey meter method. Any communication mode available, such as radio and telephone, will have to be utilized to facilitate the reporting of data. In many shelters designated as monitoring points, the only communications available may be telephones. Since there is a probability that telephone service will be disrupted, radio communication would be very advantageous.

Most of the commercially available remote monitors which are used at reactor sites and high-intensity radiation facilities are too expensive to install in all shelters. However, a development program under the direction of the OCD has been completed and a pilot production quantity has been ordered for a civil defense model of a remote-probe-type monitor designated CD V-711.[8] This system is expected to fulfill the civil defense manual remote monitoring requirements technically although lower cost units would permit wider applications. Automatic models to feed radio and telephone lines are scheduled for early development.

Although automatic monitoring systems could give a general large-scale picture of fallout patterns over large areas, other methods of monitoring are still required to determine hot spots and the finer structure of the radioactive fallout fields. The number of detectors required for an automatic system to measure the small-scale detail of a fallout field would be extremely large. If one considers that 75% of the total intensity measured at a point 3 ft above an infinite uniformly distributed source comes from a circle of 200-ft radius, it can be seen that many detectors are required to give a detailed map of a field with hot spots.[9]

The accuracy of an automatic system in measuring representative large-scale radiation intensities will be affected by small-scale variations in the fallout field due to local shielding, terrain effects, and topographical structure in an area. These effects must be considered for each particular area before an automatic system can be utilized.

On the national level, an automatic monitoring system comprised of fixed monitoring stations and control centers can effectively monitor the whole country at short times after a nuclear attack without the need for personnel on the local, or perhaps, even the county level. This can be accomplished by stationing detectors at pre-determined intervals to form a grid-like system which would present a large-scale picture of the radiation levels present throughout any geographical area. These detector points will then automatically transmit their information upon interrogation by a control center. The radiological data thus gathered can quickly be transmitted to the state or federal level and the over-all radiation intensity diagram for large areas can rapidly be determined. However, the need for radiological data is greatest, from an operational standpoint, at the local and county levels; therefore, personnel

and monitoring information are needed at these levels. If an automatic system bypassed the local levels, the state would have to send information of a primary nature back down to these levels.

The problem of immediate data needs on the local level may be solved in an automatic system by having a control center situated on the local level and manned by an operator who can record the raw data as they are being received and transmitted automatically to the next echelon. The automatic system control center can, in all likelihood, be located in the city or county control center. The raw radiological data would then be immediately available to the local RADEF chief.

Another area of possible application of an automatic system is in major industries or key sites of special interest to civil defense authorities. If a fixed automatic monitor were set up at a major industrial or other key site, the level of radiation intensity could be continually monitored and this information used in determing the optimum time for reactivation of the facility. A fixed automatic monitoring system might also be useful as an advance warning of fallout. If a city ringed its perimeter at various distances, e.g., one circle at 50 miles and one at 25 miles, with a network of automatic detector points, the RADEF personnel of that city would be forewarned of any impending fallout danger by reports from this system. The direction of the fallout path could also be determined by identifying the detectors from which the reports were coming.

The requirements for communications in an automatic monitoring system include ease of maintenance, simple decoding, and power. The maintenance problem is determined by the actual design of the telemetry or other communications systems. At present, there are numerous telemetry systems which are commercially available and can be utilized.

The power available to these systems can be a line-operated power supply with battery backup in case of power failure. The battery complement would have to be capable of providing operation for the total system (including the communications network) for an extended period.

In an automated control center, it is desirable to have a tape recording capability for recording the data and transmitting it, and a meter readout for an operator to observe. With this dual system, monitoring personnel can keep a check on any area they desire and watch the radiation levels in this area. The meter readout provides data instantly without need for decoding and the tape provides a record which could be examined closely when time permits.

In considering the possible use of an automatic system, the main objection is the expense. At present, no inexpensive automatic system is available. A cost analysis study has been made for a community monitoring system consisting of automatic stations.[10] For the City of Houston, Texas, it was estimated the initial cost of an automatic system of 15 detector points and one monitor point would be $18,400, and the monthly cost for cable pair rental and calibration would be $389. These costs do not include maintenance or a structure for the control center. It can be seen that to cover large geographical areas, this system is expensive; most cities will not be willing to spend this money.

Economic factors become important when considering the period of usefulness of an automatic system. The usefulness of a stationary monitoring point decreases with recovery time because of the need for detailed information on the radiation field caused by the small-scale effects. The length of this useful time during the fallout and recovery periods will be an important factor in determining the over-all feasibility of an automatic monitoring system and the areas of its applicability.

D. HAND-HELD PORTABLE SURVEY METERS

A general method of obtaining radiological information from a large radiation area, such as a community or a whole county in a fallout field, is the use of monitoring stations located at pre-determined positions throughout the area. The requirements of such a system are an instrument to measure the radiation intensity and a means of communicating the information to a data collection center or control room. Hand-held portable survey meters represent inexpensive versatile instruments which can be utilized in this application as well as to accompany rescue or recovery crews operating throughout the fallout area. Voice communications over radio or telephone lines are the most applicable for relaying information from hand-held, portable survey meters.

Hand-held, portable survey meters will be essential at all levels of civil defense in all phases of radiological assessment and recovery during and after a nuclear attack. The need for such instruments will increase with time after the initial attack as greater detail of the radiation field is required. During the first part of the attack period, other instruments, such as remote-probe and automatic monitoring systems, may be useful. However, as the time after an attack increases, more detailed information will be necessary and this information can most readily be obtained by hand-held instruments. Their versatility and portability make them the major type of instrument for collecting radiological data.

The accuracy of the measurement of radiation levels at specific locations is a result of numerous factors, such as terrain features and the presence of structures. To obtain a meaningful reading, the instrument itself must be used properly. If an area is to be monitored, the survey meter should be held at a height of 3 ft and read as far from structures as possible.

1. Use During the Fallout Period

At present it appears that the large number and wide distribution of hand-held instruments available at the time of an attack will make them one of the prime methods of obtaining radiological information during the attack and fallout period. Remote-probe and automatic systems might be extremely valuable, but at present they are not numerous enough to constitute a complete monitoring network in themselves. In many areas the hand-held instruments will serve as the local and fixed-station monitor.

The need and use of monitoring information in rural areas during the fallout and shelter phase is greater per capita than in populated cities, but the number of instruments per square mile will be lower. Particularly in the West, many states contain vast, sparsely populated rural areas, and portable instruments may be the only means of collecting radiological data. Monitoring information from the rural areas obtained with hand-held portable survey meters will be valuable in assessing the radiological hazard and allow the county RADEF officer to obtain relatively good fallout patterns and initiate the planning of the recovery period.

If it is decided to evacuate a small community in a rural area, hand-held survey meters would be the only sources of radiological information. Designated monitoring stations using portable survey meters in rural communities are an important part of an integral monitoring system of any civil defense program.

The problems associated with the use of hand-held survey meters as a method of collecting radiation data in populated areas are similar to those encountered in rural areas. The instruments will be used primarily to assess the hazard on a larger community level. Information from some remote-probe

monitors and automatic systems may be available, but in decisions requiring a detailed analysis of the fallout field, hand-held instruments will be of greater use. Many populated areas may suffer blast and thermal damage as well as fallout radiation. If the detonation is a surface burst, and if the wind velocity is low, some fallout will occur in areas of light-to-medium blast damage, even upwind from the detonation. The degree of hazard may not be too high to prevent life-saving rescue operations. In these instances, hand-held survey meters will be used to determine the hazard associated with entry into the damaged region.

2. Use During the Recovery Period

During the initial phase of the recovery period, fallout pattern contours should be completed in as much detail as possible. Aerial and mobile monitoring systems using portable survey instruments are important in this period; however, hand-held portable survey instruments will become increasingly useful during the later phases of the recovery period. As a community becomes more organized, more detailed information is necessary.

Individual and community decisions must be made during the recovery period. Before a better shelter is chosen, it must be monitored and before any movement of people is attempted, new areas and routes to them must be monitored. These decisions require wide use of hand-held instrumentation.

Complete recovery will involve revitalizing important industries and facilities as soon as possible, for example, hospitals, power plants, telephone centers, major plants of heavy industry, and supply centers. To determine safe stay times and working schedules, detailed monitoring with survey meters must be performed in specific locations and buildings. Routes to these locations must also be monitored. If certain key facilities are to be decontaminated, hand-held portable survey meters must be used to measure the radiation levels before and after decontamination.

VI. INSTRUMENTATION AND EQUIPMENT

Most commercially available instruments applicable to the methods of obtaining radiological information have been investigated. Data collection and handling equipment is included in the study of the communications instrumentation. An examination of instrumentation and equipment was made in the following categories:

1. Hand-held portable survey meters
2. Remote-probe and automatic monitoring instrumentation
3. Proposed detector types
4. Data handling instrumentation including display and processing equipment
5. Communication equipment applicable to all levels of command.

A. HAND-HELD, PORTABLE SURVEY METERS

The most important instrument used in radiological monitoring of fallout fields is the hand-held, portable survey meter. Unlike a fixed monitor, the hand-held, portable survey meter can be taken to the location where and when it is needed. Portable meters are available in a wide range of sensitivities and are used in gross hazard evaluations as well as low-level contamination surveillance. Portability, versatility, and low cost contribute to the widespread use of portable equipment in civil defense monitoring systems.

Many characteristics, parameters, and qualities are important when considering portable instrumentation for civil defense use. Some of these are:

1. Type of detector
2. Measurable range of radiation intensity levels
3. Type of radiation detectable and differentiation possible
4. Energy response
5. Ease of operation
6. Readings which are not ambiguous
7. Rapidity of obtaining a reading (response time)
8. Instrument drift
9. Ease of maintenance
10. Ease of calibration
11. Battery life
12. Use of easily obtainable batteries
13. Weight
14. Ruggedness
15. Ability to withstand environmental conditions
16. Cost

The first four of these points concern the basic type of instrument and will be determined by the intended use. A high-level gamma-ray meter will probably be an ionization chamber with 500-1000 r/hr high-level readability. The energy response is of special interest in civil defense instrumentation because a relatively large amount of fallout gamma rays are in the low kiloelectron volt energy range and it is not desirable to have an instrument in which the response varies for low-energy photons.

Points 5, 6, 7, and 8 are associated with obtaining the readings. The instrument should have a minimum of controls because it may be used by inexperienced personnel and because complicated operation lengthens the reading time and the exposure to the operator. When a reading is taken it should be very explicit and no ambiguity should exist as to what range is being used. Also, the response time of the instrument should be short to minimize the time necessary to take a reading.

Points 9, 10, 11, and 12 are important because the number of instruments will be great and if the cost per instrument for these items is kept at a minimum, an appreciable savings will result. The use of easily obtainable batteries is important in an emergency because special batteries may not be available. Points 13, 14, and 15 deal with the physical properties of the instrument and are important because of the type of service civil defense instruments are likely to receive. Field service in all weather conditions and transportation in all types of vehicles demand rugged and durable instruments.

The cost of the instrument, Item 16, is one of the most important items to consider. The cost of the portable civil defense instruments necessary for coverage of an area as large as the United States will be great and ultimately will be borne by all the taxpayers.

Some properties of portable instruments not tabulated above are more general and can be explored only through experience with the instrument. These properties include reliability, dependability, and long-term stability. Psychological factors also enter into the choice of instruments. An individual may not choose to risk his life on an instrument in which he has no confidence. Such an instrument may operate well but be poorly constructed or packaged.

The most readily available and common portable survey meters and dosimeters were examined from the viewpoint of a potential customer. A compilation of some of these instruments is given in Table 1. The limits of accuracy and reliability quoted are those given by the manufacturer.

B. REMOTE-PROBE AND AUTOMATIC MONITORING INSTRUMENTATION

Remote-probe and automatic monitoring systems refer to that instrumentation which permits radiological monitoring with the detector at a considerable distance from the readout equipment. Some of the remote-probe instruments are listed in Table 2. This concept includes all types of instruments from a hand-held portable survey meter with a cable connecting the detector a few feet away, to a completely automated system consisting of a detector with a radio or telemetry unit located possibly several miles away from an automated receiving, decoding, recording, and transmission center. As discussed previously, the term "remote-probe monitor" refers to the shorter range, cable-connected systems with a manual readout requiring personnel for operation, while the term "automatic systems" refers to instruments of longer range, utilizing radio or hardwire transmission of data to a control center. In automatic systems the control center may or may not be fully automated.

Inasmuch as some remote-probe monitors are essentially portable instruments modified for remote capability, the numerous points of discussion on characteristics, parameters, and qualities given in the previous section apply equally well to remote-probe monitoring instruments. These instruments may or may not be battery powered and may have a variety of sensors depending on their intended use. Qualities not applicable to portable instruments are blast resistance and distance between sensor and readout.

TABLE 1. Tabulation of Available Portable Survey Meters and Dosimeters

TYPE	MFGR.	MFG. DESIGNATION	RANGE	ENERGY RESPONSE	SENSITIVITY	REPRODUCIBILITY	BATTERY COMPLEMENT	RETAIL PRICE
GM or Scintillation Probe	Victoreen	"Thyac II" Model 489	0-800 counts/min 0-8,000 counts/min 0-80,000 counts/min	-	α,β,γ	±10%	4-"D" Cells	$175.00
Ion Chamber Dynamic capability Electrical circuitry	Victoreen	Model 440 Low-energy	(mr/hr) 0-3, 0-10, 0-30, 0-100, 0-300	±15% 6.5 kev - 1.2 Mev ±5% 80 kev - 1.0 Mev	β-γ	±10% 100 kev - 1.2 Mev ±15% 6.5 kev - 1.2 Mev	4-"D" Cells	595.00
Ion Chamber	Victoreen	Model 592B	(mr/hr) 0-10, 0-100, 0-1,000	±10% 50 kev - 1.3 Mev	γ	±10% of full scale	3-1.3V 6-22.5V	325.00
Ion Chamber	Victoreen	Model 740 "Cutie Pie"	740; 0-0.1, 0-1, 0-10, r/hr 740A;0-0.05, 0-0.5, 0-5, r/hr 740B;0-0.025, 0-0.25, 0-2.5 r/hr	±15% 40 kev - 2 Mev	α,β,γ	±10% of full scale	4-22.5V 1-1.3V	295.00
Ion Chamber	Victoreen (Jordan)	Model AGB-10KG-SR "Radgun"	0.01 mr/hr - 10,000 r/hr in 3 ranges	80 kev - 1.2 Mev "Essentially Independent"	β-γ	±15%	3-30V; 3-1.34V 1-5.0V	445.00
Ion Chamber (N-W)	Victoreen (Jordan)	AGB-50B-SR AGB-500B-SR	0.05-50 mr/hr, 0.05-50 r/hr 0.5-500 mr/hr, 0.5-500 r/hr	80 kev - 1.2 Mev 80 kev - 1.2 Mev	β-γ β-γ	±15% ±15%		295.00 295.00
Ion Chamber (N-W)	Victoreen (Jordan)	"Minirad" M-50, M-200	0.005 - 50 r/hr 0.02 - 200 r/hr	±25% 80 kev - 1.2 Mev	γ	±30%	1-5.2V 1-1.34V	129.50
GM Tube	NMC*	GS-3L	0-0.2 mr/hr 0-2 mr/hr 0-20 mr/hr	-	β-γ		"D" Cells	195.00
Ion Chamber	TA**	CP-3 "Cutie Pie"	0-0.05 r/hr 0-0.5 r/hr 0-5 r/hr	-	α,β,γ	±10%	4-22.5V 2-1.35V 2-6.5V	295.00
Ion Chamber	TA**	Juno, SRJ-7; HRJ-7	0-0.05 SRJ-7 0-0.5 SRJ-7 0-5 SRJ-7	-	α,β,γ	-5%	4-22.5V 2-1.35V 2-6.5V	325.00
			0-0.25 HRJ-7 0-2.5 HRJ-7 0-25 HRJ-7	-	α,β,γ	+10%	4-22.5V 2-1.35V 2-6.5V	325.00
GM Tube	Eberline	Model E-300	0-0.2 mr/hr 0-2 mr/hr 0-20 mr/hr	-	β-γ	15%	2-67.5V 9-1.34V	750.00
GM Tube	Eberline	Model E-500B	0-0.2 mr/hr 0-2 mr/hr 0-20 mr/hr 0-200 mr/hr 0-2,000 mr/hr	-	β-γ	15%	5-"D" Cells	550.00

TABLE 1, Continued

TYPE	MFGR.	MFG. DESIGNATION	RANGE	ENERGY RESPONSE	SENSITIVITY	REPRODUCIBILITY	BATTERY COMPLEMENT	RETAIL PRICE
Scintillation	Eberline	Gadora-1	0-1 r/hr 0-10 r/hr 0-100 r/hr 0-1,000 r/hr	-	γ	8%	5-"D" Cells	$400.00
Ion Chamber	Baird Atomic	Model 414	Log Scale 3 - 3,000 mr/hr	±15% from 80 kev - 2 Mev, 0.9 mg/cm² mylar window	α,β,γ	20%	4-1.3V 1-5.2V 3-22.5V	395.00
Ion Chamber	NIA***	RS-40	0-0.02 r/hr 0-0.2 r/hr 0-2.0 r/hr 0-20 r/hr	-	γ	-	5-22.5V 2-1.5V	275.00
Ion Chamber	NIA***	C-1A	0-50 mr/hr 0-500 mr/hr 0-5,000 mr/hr	0.7 mg/cm² θwindow	-	10%	4-22.5V 1-1.5V	-
GM Tube	NIA***	RS-30	0-0.16 mr/hr 0-1.6 mr/hr 0-16 mr/hr	Probe A - 35 mg/cm² Probe B - 1.4 mg/cm² end window Probe C - 35 mg/cm²	β-γ α,β,γ β-γ	-	5-"D" Cells	285.00
GM Tube	NCA*	RM2B	6 ranges 0-0.25 up to 0-25 mr/hr	-	Probe PM5, β-γ Probe INAA, α,β,γ	-	-	-
GM Tube	NC‡	2612, 2 probes M or P	0-0.2 mr/hr 0-2 mr/hr 0-20 mr/hr	P 1.4 mg/cm² mica window	Probe M, β-γ Probe P, α,β,γ	10%	2-67.5V 2-1.5V	255.00 295.00
Ion Chamber	NC‡	2586, S T Interchangeable Chambers	S: 0-25 mr/hr, 0-250 mr/hr, 0-2,500 mr/hr T: 0-2.5 r/hr, 0-25 r/hr, 0-250 r/hr	10 kev - 3 Mev	α,β,γ	10%	4-30V 2-15V 4-1.3V	S475.00 T545.00
Ion Chamber Direct-Reading Dosimeter	NC‡	NC-402	0-200 mr	20%, 80 kev - 2 Mev	γ	10%	-	38.00
Dosimeter Charger	NC‡	NC-403	-	-	-	-	1-"D" Cells	39.50
Ion Chamber Direct Reading Dosimeter	Landsverk	L-49	200 mrem	-	Y	-	-	45.00
Ion Chamber Direct-Reading Dosimeter	Landsverk	L-50	0-200 mr	15%, 80 kev - 2 Mev	γ	10%	-	38.00

TABLE 1, Continued

TYPE	MFGR.	MFG. DESIGNATION	RANGE	ENERGY RESPONSE	SENSITIVITY	REPRODUCIBILITY	BATTERY COMPLEMENT	RETAIL PRICE
Ion Chamber Direct-Reading Dosimeter	Landsverk	L-51	0-5r	15%, 80 kev - 2 Mev	[illegible]	10%	-	$ 48.00
Ion Chamber Direct-Reading Dosimeter	Landsverk	L-52	0-10r	15%, 80 kev - 2 Mev	[illegible]	10%	-	48.00
Ion Chamber Direct-Reading Dosimeter	Landsverk	L-53	0-20r	15%, 80 kev - 2 Mev	[illegible]	10%	-	48.00
Ion Chamber Direct-Reading Dosimeter	Landsverk	L-54	0-50r	15%, 80 kev - 2 Mev	[illegible]	10%	-	48.00
Ion Chamber Direct-Reading Dosimeter	Landsverk	L-55	0-100r	15%, 80 kev - 2 Mev	[illegible]	10%	-	48.00
Ion Chamber Direct-Reading Dosimeter	Landsverk	L-56	0-600r	15%, 80 kev - 2 Mev	[illegible]	10%	-	48.00
Dosimeter Charger	Landsverk	L-24K	-	-	-	-	1-"D" Cell	49.00
Ion Chamber Direct-Reading Dosimeter	Victoreen	Model 754	0-0.2r	±10%, 40 kev - 1.2 Mev	[illegible]	-	-	35.00
Ion Chamber Direct-Reading Dosimeter	Victoreen	Model 541 A	0-0.2r	±10%, 55 kev - 2 Mev ±15%, 45 kev - 2 Mev	-	-	-	38.00
Transistorized Charger	Victoreen	2000 A	-	-	-	-	1-"D" Cell	40.00

* Nuclear Measurements Corporation
** Technical Associates
*** Nuclear Instruments & Accessories Incorporated
† Nucleonic Corporation of America
‡ Nuclear Chicago

TABLE 1, Continued

TYPE	MFG. DESIGNATION	RANGE	ENERGY RESPONSE	SENSITIVITY	REPRODUCIBILITY	BATTERY COMPLEMENT	GOV'T PRICE
Civil Defense Portable Survey Meters and Dosimeters.*							
GM Tube	CD V-700	0-0.5 mr/hr 0-5.0 mr/hr 0-50.0 mr/hr	-	β-γ	±15%	5-"D" Cells	$19.25
Ion Chamber	CD V-715	0-0.5 r/hr 0-5.0 r/hr 0-50.0 r/hr 0-500.0 r/hr	±15% 80 kev - 1.2 Mev	γ	±20%	1-"D" Cell	15.86
Ion Chamber	CD V-720	0-5 r/hr 0-50 r/hr 0-500 r/hr	±15% 80 kev - 1.2 Mev	β-γ	±15%	2-"D" Cells	23.30
Ion Chamber	CD V-710	0-0.5 r/hr 0-5.0 r/hr 0-50.0 r/hr	±15% 80 kev - 1.2 Mev	γ	±20%	2-"D" Cells 1-22.5 V	17.50
3 GM Tubes, Aerial Monitor & Recorder	CD V-781	0-0.1 r/hr 0-1 r/hr 0-10 r/hr	±20% 80 kev - 1.2 Mev	γ	±10%	8"D" Cells	748
Quartz Fiber Self Reading Dosimeter	CD V-138	0-200 mr	±20% 80 kev - 2 Mev	γ	±10%		4.70
Quartz Fiber Self Reading Dosimeter	CD V-730	0-20r	±20% 80 kev - 2 Mev	γ	±10%		4.75
Quartz Fiber Self Reading Dosimeter	CD V-740	0-100r	±20% 80 kev - 2 Mev	γ	±10%		4.75
Quartz Fiber Self Reading Dosimeter	CD V-742	0-200r	±20% 80 kev - 2 Mev	γ	±10%		4.20
Quartz Fiber Self Reading Dosimeter	CD V-736	0-2r special scale	±20% 80 kev - 2 Mev	γ	±20%		2 dosimeters + charger: $24.95 commercial price
Quartz Fiber Self Reading Dosimeter	CD V-746	0-600r	±20% 80 kev - 2 Mev	γ	±20%		
Charger	CD V-750	charges CD V-138, 730, 740, 742				1-"D" Cell	3.70

*R. B. Martin, "Instruments for Civil Defense." Health Physics Journal 6, 216-217, October, 1961.

TABLE 2. Remote-Probe Monitors

Type	Mfgr.	Mfg. Designation	Range	Energy Response	Sensitivity	Reproducibility	Portable	Power Supply	Retail Price	Remarks
Ion Chamber	Victoreen	Remote Area Monitoring Systems	10^{-5}-10^{6} r/hr	γ ±10% 80 kev - 2 Mev	β-γ	±15%	No	115V - 60 cps		Rack-mounted unit with 20-channel capability. Price depends on number of channels.
Ion Chamber (N-W)	Victoreen (Jordan)	AG-50-P AG-500-P	0.05-50 mr/hr 0.05-50 r/hr 0.5-500 mr/hr 0.5-500 r/hr	80 kev - 2 Mev	γ	±15%	Yes	Batteries	$330.00	These two instruments are the AGB-50B-SR and AGB-500B-SR survey meters with probes on 25 feet of cable.
Geiger Tube	Lionel-Anton	LEL-777-A	0-100 r/hr Log Scale	-	-	-	Yes	4-"D" Cells	99.50	Available with as many as three remote detectors on cables of 25, 100, 300, or 1000 feet in length.
Ion Chamber	Nuclear Chicago	Models 2586 S&T Interchangeable Chambers	S- 0-25 mr/hr 0-250 mr/hr 0-2500 mr/hr T- 0-2.5 r/hr 0-25 r/hr 0-250 r/hr	10 kev - 3 Mev	α-β-γ	±10%	Yes	4-30V Batteries 2-15V Batteries 4-1.3V Batteries	-	Available with Model PC43 6-foot rigid aluminum probe or Model PC33 10-foot flexible cable. Also available with chambers to raise sensitivity.
Ion Chamber	Technical Associates	CP-TP-1A CP-TP-1B	0.5, 5, 50 r/hr 50, 500, 5000 r/hr	-	β-γ γ	-	Yes	4-22.5V Batteries 2-7.5V Batteries 2-"D" Cell Batteries	460.00 440.00	Has 40-inch extension with 3-position chamber.
Ion Chamber	American Nuclear Corp.	ANC-102B	2-100 mr/hr	-	γ	-	-	-	395.00	Four station remote monitoring system which includes 4 extension probes and audio-visual alarms.
Ion Chamber	American Nuclear Corp.	ANC-101B	2-100 mr/hr	-	γ	-	-	-	199.50	Single station remote monitoring system.
Ion Chamber	American Nuclear Corp.	ANC-201-100	2-100 mr/hr	-	γ	-	-	-	395.00	Single channel with fail-safe features.
GM Tube	American Nuclear Corp.	ANC-100XL	0-100 mr/hr 0-1000 mr/hr	±20% 50 kev - 2 Mev	α-β-γ	±15%	Yes	2-1.5V penlight	169.50	Price quoted for 0-100 r/hr range with extension for γ monitoring. Range up to 0-1000 r/hr available.
Scintillation	Eberline	HILEM-1	0-100 r/hr 0-1000 r/hr	-	γ	Linearity ±8% of Full Scale	Yes	4-"D" Cells or 4-RM42 Hg cells or Sonotone Ni Cd "D" cells	279.00	Detector can be placed a considerable distance from control unit. Higher range available.
Ion Chamber		CDV-711	0-1 r/hr 0-10 r/hr 0-100 r/hr 0-1000 r/hr	±15% 90 kev - 1.2 Mev	γ	±15%	No	9-"D" Cells	-	Blast-proof detector on 300-foot cable.
Ion Chamber		CDV-717	0-.5 r/hr 0-5 r/hr 0-50 r/hr 0-500 r/hr	±15% 80 kev - 1.2 Mev	γ	±20%	Yes	1-"D" Cell	30.82 (government price)	25-foot remote capability.

In some applications the use of a blast-resistant sensor is important. At least one remote-probe instrument has been developed for monitoring the radiation intensity outside a shelter where blast forces might be significant. Portable remote-probe instruments are useful in applications where the entire instrument must be relocated frequently. A meter is most commonly used on existing remote monitors for readout. Digital or tape readouts are possible but only complicate the instrument for field use. By keeping the instrument simple, the maintenance time can be minimal which will allow a more efficient utilization of the equipment. The cost of the digital readout is decreasing. The digital readout is the most likely alternative to a meter. However, the added benefit in readability is not sufficient to demand a changeover from meter readouts at this time. For reporting, the operator can read a meter in essentially the same time as a digital readout.

Two automatic radiological monitoring systems[11,12] have been used experimentally in the field. These systems are summarized in Appendix B. These systems and proposed systems[10,13] that have been studied are not recommended for state and local civil defense use.

C. SOME PROPOSED DETECTORS

With the advent of semiconductors, a new concept in radiation detector was conceived, the solid state ionization chamber. In a phosphorus-diffused silicon P-N junction with a reverse bias voltage applied, a depletion, or space-charge, region exists on both sides of the junction and function like an ion chamber with the passage of charged particles. However, the gamma sensitivity is very low in this particular detector and further research is being carried out.[14] It has been shown the Li-diffused silicon exhibits a measurable gamma sensitivity.

Using a Li-diffused silicon P-N junction and a Co-60 source, Baily and Mayer[15] observed a gamma sensitivity of 250 counts/min/mr/hr of which 60 counts/min were background.

Gamma sensitivities for commercially available silicon diodes (P-N) were measured by Lindsay at the University of California Research Laboratory, Livermore, California.[16] If Compton scattering takes place in the depletion region, the Compton electrons create a current in this region by creating hole-electron pairs. This current and the current produced by minority carriers make up the main current which is a measurable function of the gamma-ray intensity.

The sensitivity of a silicon P-N junction was calculated to be $S \simeq 5 \times 10^{-19}$ amp/cm^2 of junction area per micron of depletion layer width per Mev/cm^2-sec for 1- to 3-Mev gamma rays. A number of selected commercially available diodes and transistors were studied[16] to verify these calculations. Radiation sources used were Co-60, a pulsed reactor, and a linear accelerator which produced a gamma field from steady state to pulses of 0.02-μsec duration. The experimentally determined sensitivities were in substantial agreement with the calculated value.

Another approach to making these devices more sensitive to gamma radiation is to form an N-I-P junction. In this method, a piece of high-resistivity, p-type silicon has p layers and n layers diffused on opposite ends and then a reverse bias applied. This enables the space-charge region to extend throughout the silicon wafer and increase the sensitive volume. The diffused layers may be either phosphorus or lithium, and silicon and germanium have both been used as the wafer. Various experiments[17,18,19] have been carried out with these detectors and an increase in gamma-ray sensitivity has been noted.

The use of solid state detectors also includes CdS crystals. In this case, however, the photoconductivity of a crystal, not the ionization current, is a measure of the gamma radiation. This property was investigated in 1956 by Hollander.[20] The conductivity of a CdS cell was found to vary from 10^{-11} ohm^{-1} cm^{-1} dark to 2 x 10^{-5} ohm^{-1} cm^{-1} to a 100-r/hr, 100-kev x-ray beam. With such a large dynamic resistance change no amplification is necessary. Only a battery, CdS crystal, and a conventional meter are required for a complete unit. The x- and gamma-ray spectral response has been found to extend from below 30 kev to above 2 Mev. The dose rate range can extend from 1 to millions of r/hr.

The rise time of these crystals is long and one of the major disadvantages for low-intensity measurements. Hollander found that a particular crystal required 270 sec to achieve 85% of steady-state conductivity in a 50-r/hr, Co-60 field. This effect can be minimized by radiation biasing with an internal radium source. With a bias of 0.05 r/hr the rise time in the previous case was reduced to 9 sec for 85% of steady-state condition.

The spectral response of these crystals can be reduced to ±12% from 80 kev to 1.3 Mev by a 1/16-inch lead filter with five 0.07-inch holes per quadrant.[20]

The crystal conductivity was found to be linear as a function of intensity from 10^{-1} to 10^{5} r/hr. The temperature independence of these crystals is also very good and the variation in conductivity due to temperature was less than ±15% from -20 to 80°C.

With specially prepared gamma-sensitive cells having the above properties, Hollander found the sensitivity to gamma radiation to be 2 μa/r/hr at 100 volts. This response is

10,000 times that of selected high-sensitivity commercial CdS photocells.

Some commercial CdS photocells were investigated as gamma-ray detectors at Wright-Patterson Air Force Base.[21] Data were taken on the change in conductivity caused by gamma-ray exposure at dose rates of 1.4×10^3 to 5×10^5 r/hr. The voltage on the crystals was varied from 10 to 100 volts and the current change in the mentioned dose rate and voltage range was from 1 to 10,000 μa. It can be seen that these crystals are much less sensitive than those prepared by Hollander.

Considerable research has been done at the U. S. Naval Radiological Defense Laboratory by Redmond[22] on the usefulness of CdS crystals as detectors for gamma monitoring systems. The same advantages and disadvantages listed before were in evidence with the exception that extreme variation in sensitivity between crystals was encountered. Each crystal exhibited a permanent set, or change in calibration, after temperature-dependence studies were completed which indicates that each crystal would have to be recalibrated after is has been subjected to a high temperature.

Although this brief observation of solid state detectors has shown a number of technical difficulties, the advantages of such devices should not be overlooked. The P-N and N-I-P junction devices are extremely small and yet rugged enough for utilization in a field-type survey instrument. The voltages used are low enough to be readily available in a portable instrument. The range of radiation intensity covered by one detector can be made as large as the limit of readability of the electronics used for amplification. At present, four decades can easily be covered; however, these dose rate ranges are rather high and to detect low levels much development and

research must be done. These solid state detectors can be used in a laboratory environment now and the results of the studies made indicate the feasibility of using these detectors in radiation monitoring systems when the proper advancements have been made in the technology of these devices.

The CdS crystals are also very rugged and small. These advantanges coupled with the low-impedance circuitry and low power consumption associated with CdS crystals could make these devices desirable for portable survey equipment and remote area monitoring equipment. These detectors, because of the variations in sensitivity between crystals grown in the same batch, also need further research and may one day fulfill the need for a wide-range, rugged detector. The ranges presently covered can be six decades (1 to 10^6 r/hr).

In general, solid state detectors possess all the advantages required for a useful survey instrument but further studies must be made to solve technological problems before these devices can be gainfully employed in a practical instrument. This field of research should be followed to take advantage of the earliest possible improvements and developments which may permit the use of these detectors in practical monitoring systems.

D. COMMUNICATION INSTRUMENTATION

1. Introduction

The present civil defense communication systems at the various levels are comprised of several different communication networks. It is clear that a civil defense program will be totally inoperable without adequate communication. Reliance in any one network in time of nuclear attack is unrealistic and provision must be made for the use of alternate networks should any communication link fail to be operational

under emergency conditions. While it is beyond the scope of this study to examine those effects which can disable a communication system, it is appropriate to describe applicable systems currently operational in the United States.

2. National Communications Systems

1. The NACOM-I (National Communications System) is a teletype and voice line facility common to all federal OCD regions. For Region 7, direct connection is made from Santa Rosa to the civil defense headquarters in California, Utah, Arizona, and Nevada.

   The NACOM-I is a full duplex teletype system which permits transmitting and receiving information simultaneously and provides for alternate voice communication. Originally, this system connected all the federal regions to Battle Creek, Michigan and Washington, D. C., but now it functions between federal regions and their corresponding states. As a replacement of NACOM-I, the SCAN system was adopted on September 1, 1962 for national communications.

2. The SCAN (Switched Circuit Automatic Network) system (developed by the A.T.&T., Company to provide an inter-communication network for the military establishments within the continental United States) consists of four automatic switching centers interconnected by long distance trunk lines. The four centers are located at Frederick, Maryland; Hillsboro, Missouri; Rockdale, Georgia; and Santa Rosa, California. Various U. S. Army installations and other specified governmental installations (including regional OCD) are connected to this network by leased long distance communication channels. The SCAN system essentially provides all the modes of communications of the NACOM-I system and also combines the military and federal regional OCD in the same system.

3. The TWX (Telephone Company Teletype Wire Exchange) system provides land line teletype communications services between various points throughout the country. Many industrial and commercial corporations subscribe to this system and each is provided with a transceiver teletype machine. Messages may either be sent to, or received by network members; however, simultaneous

transmission and reception is not possible. There is no provision for voice communication capability in this system. Most federal regions, states, and many cities subscribe to the TWX.

4. The Western Union system provides teletype service throughout the continental United States. Reperforators and receivers are supplied to handle the flow of messages and all the office equipment and land lines are leased from Western Union. The facilities of this system are available to virtually all civil defense levels and organizations.

5. The Telephone Company system is the standard land line telephone subscriber system providing voice communications. However, in the event of emergency or disaster, direct lines are provided to the state OCD headquarters from the federal regions and between many local and state offices.

6. The Kineplex system provides a versatile high-speed, medium-capacity, data communications system for conveying binary information over telephone transmission facilities. It has a built-in transmitter that retransmits the same data received back to the OCD National Headquarters indicating the circuit is closed. The SCAN system facilities are utilized as the receiving and transmitting medium. All but two Federal Regions have the Kineplex system.

7. The Federal Aviation Agency Weather Network provides weather data from all major commercial airports in the United States. Teletype receivers and land lines are leased from the telephone companies and tied to the local FAA. Fallout prediction data are transmitted four times daily over this system.

8. The NAWAS (National Warning System) is designed primarily for attack warning and serves over 500 nationwide locations. This land line system provides voice communications from NORAD in Colorado Springs to the federal regions, states and regions within each state.

9. The NACOM-II (National Communication System II) provides basic radio backup to NACOM-I and can handle all the teletype and voice equipment normally handled by the NACOM-I system. It is a high frequency radio

system using government-assigned frequencies and operates in the single side band mode. Facilities for this system have not yet been constructed in all state capitals.

10. The RACES (Radio Amateur Civil Emergency System) is an organized network of amateur radio operators and provides emergency communication services between the federal regional control centers and the states within the regions. This system is under the supervision of the radio chief in the federal regions and states, operates on government-assigned frequencies, and handles messages in the event NACOM-I, NACOM-II, and SCAN become inoperative. All levels of the civil defense organizations have the RACES network sponsored by the national OCD through the national regions.

11. The MARS (Military Affiliate Radio System) is the military counterpart to the civilian RACES organization. This network is comprised of military personnel who are amateur radio operators.

12. CONELRAD is a warning system provided by local radio stations in conjunction with the state, sub state, and local regional control centers. However, other information pertinent to existing conditions and instructions during an emergency of disaster is also transmitted. Initially, only certain stations throughout a state were designated to operate in the CONELRAD system on two preassigned frequencies, 640 and 1240 kc. All stations, including Commercial TV stations, can now participate in the system while operating on their normally assigned frequencies.

3. Typical State and Local Communications Systems

   a. Telephone Subscriber Service

   b. Local Radio and TV Stations

   c. State and City Police Radio

   d. Fire Department Radio

   e. State Division of Highways Radio

Each vehicle is supplied with a two-way radio. Also each local headquarters can communicate with adjacent stations and the state headquarters.

f. State Division of Forestry Radio

Two-way radios are provided in cars, fire-watch stations, park headquarters, and animal refuges.

g. Mutual Aid System (MAS)

This is a state-wide system of mutual assistance which begins at the city level. The MAS uses the Disaster Communication System (DCS), the Special Emergency Radio System (SERS), and various local government networks.

h. Inter-Cities Law System (ICLS)

Both teletype and voice communications can be handled by this system. Not all localities have a tie-in to this system.

4. Equipment

a. Handie-Talkie

b. Telephone

c. Vehicular Radio

d. Fixed Station Amateur Radio

The fixed station radio equipment used by amateurs is not restricted in size and weight. The equipment varies greatly between installations and little standardization exists. The advent of single side band (SSB) transmission has improved the over-all performance of this communication equipment. Many amateurs are employing SSB equipment because it offers greater radiated power, is less susceptible to atmospheric and man-made noise interference, and effectively increases the operating range and reception quality.

e. Teletype

The teletype equipment used throughout the country consists of three kinds of sets. Most installations employ the

transmitter-receiver combination which sends and receives messages over telephone leased lines. Some users employ machines which only receive. The receiver-reperforator while receiving the message in the normal print-out manner also codes a tape with the same message. This tape, in turn, can then be inserted into a transmitting machine for relaying the message to another point or kept as a record.

The machines used by commercial systems have a duplex or multiplex capability. This feature allows messages to be sent and received simultaneously on the same circuit, but it requires the services of two machines. Otherwise, with a single transmitter-receiver unit, transmitting and receiving must be time shared.

f. Radio-Teletype

Radio-teletype equipment employs r-f transmission. The terminal machines are standard teletype equipment. It is more reliable and faster than any voice system but not as reliable as the land line system.

g. Remote Control Portable Radio Repeater

The remote control radio repeater is an instrument which transmits only when triggered by the proper coded signal. The repeater must be in the line-of-sight from the previous repeater. Once the repeater network has been activated, two-way communications can be maintained. Repeater equipment which is remotely located requires a self-contained power unit.

h. Single Side Band Transceivers (SSB)

The single side band transceivers function exactly like other radio transmitting-receiving gear except that the transmitted power appears in one of the side bands instead of in the carrier and two side bands. The system efficiency is improved, interference is reduced to a negligible amount, and less r-f power is required.

5. <u>Reliability and Use of Communications Systems</u>

In discussing the reliability of communications systems under conditions of a nuclear attack, the number of variable parameters which will affect communications must be considered. Atmospheric ionization, which results in transmission loss for some indefinite period is a problem confronting radio communications in the vicinity of a nuclear explosion. The variables effecting the magnitude of this effect includes height of burst, yield, and weather. Reliability cannot be accurately stated when considering variables which will not be known in advance.

To make a broad prediction of what may be expected, the past experience in weapons test series can be cited. According to Reynolds Electrical and Engineering Company (REECO),* which conducts off-site monitoring and maintains communication networks for the AEC at both the Nevada Test Site (NTS) and the Pacific Proving Grounds (PPG), the radio communications have never been interrupted at the NTS and have only experienced intermittent losses at the PPG. The longest interruption was for 40 minutes after a high-altitude shot. The radio communications used include UHF, VHF, and HF, and were air-to-ground as well as ground-to-ground.

A SSB radio-telephone system of the scatter system type has been used to link Eniwetok and Bikini and was never interrupted under any conditions attributable to weapons testing. This system used a 120-mile path length and was operated as a radio-telephone link for daily communications.

The antenna used on any particular system presents another problem. The antenna must withstand the blast associated with nuclear detonations, or radio communications will not be possible.

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*Private Communication, K. Heines to T. Dahlstrom, May 14, 1963.

The AEC is sponsoring a study on the hardening of antennae sites to withstand 12 psi and still be operable. One possible solution is to use antennae mounted on hydraulic rams which can be retracted and extended at will. The vulnerability of antennae to blast and thermal damage presents a major problem of radio communications.

If an antenna survives the initial blast and thermal damage, the consideration of particular types of antennae becomes another variable in the atmospheric ionization problem. If an antenna frequency system has a low angle of emission it is likely not to be affected by ionization, whereas systems with high angles of emission may encounter ionization regions more readily. However, no extensive study of this problem for a multi-burst situation has been performed.

It has been found that atmospheric ionization has not presented a communications problem in weapons testing series and that hardened antennae sites would greatly enhance the probability of radio communications.

The use of local government agencies communications networks has been stressed in previous chapters of this report. The following is the general reliability to be expected from these systems (full duplex circuit) and from a SSB system used in a county/sub-state control center:

City agencies and local monitors	160 Mc (FM)	95% reliable
County agencies to county control center	30-54 Mc (FM)	95% reliable (protection of repeater necessary)

County to sub-state	SSB 2-6 Mc	85% reliable	short-range
Sub-state to state		95% reliable	long-range

The SSB equipment operating at 2 to 6 Mc, 175 watts should be reliable for 500-mile range. Radio transceivers in the 160-Mc

range are available from one manufacturer on a rental basis of 9%/month of the value. These transceivers could be used in shelters, and after being leased for a year, the unit is considered purchased.

Hard wire communications are not susceptible to atmospheric ionization but can be greatly affected by the electromagnetic field (EM effect) set up by nuclear detonations. If the EM effect is large, terminal equipment will be damaged at either or both ends of a particular cable. There have been instances where blocking relays have been tripped at great distances from a nuclear test. Central switchboards may be rendered inoperative by this effect, either directly, or by damage to other components on the line. The telephone system has many alternate routes, especially in large cities, and it is likely that in the event of several line failures, a route will still exist from which one central office can reach another.

6. Data Handling

The present methods of data handling at all levels of the civil defense organization are largely manual and require considerable time and effort to digest and interpret the radiological information. The use of automatic data handling and data reducing equipment at the local levels is generally precluded by the cost of such equipment and should not be necessary for handling the quantity of data that will exist at the local centers. However, the use of business computers at state and national levels would greatly facilitate the analysis of the large volume of data which these offices will receive. Such computers already exist within various state and federal governmental agencies and could be made available to the civil defense program.

While the reporting of data from the local level will most probably be carried out by telephone or radio, rapid dissemination of data at the higher echelons can be facilitated by commercially available systems such as teletype (both land line and radio), facsimile transmission, and various forms of telemetry. Data formats compatible with these transmission systems can be used as the input and output formats of the business computers. Data from these computers can be used to prepare the contour maps.

VII. RADIATION INTENSITY VARIATIONS AS A RESULT OF SMALL-SCALE EFFECTS

A. INTRODUCTION

The variations in the fallout field have been described as being caused by two influences: small- and large-scale effects. The large-scale effects relate fallout and the radiation intensity pattern on the ground from an idealized situation of evenly distributed fallout on a smooth infinite plane. Small-scale effects describe those perturbations of the large-scale pattern caused by local conditions. Examples of small-scale effects which will alter the actual observed radiation intensity at any given location from that predicted by examination of the large-scale effects are ground roughness, distribution of fallout on vegetation, geometry of terrain, local shielding by structures, and vegetation and weathering.

For civil defense operations, the general or large-scale pattern of radiation intensities over an area must be known by administrative and coordinaing personnel so they can make initial assessments of the radiological hazard.. The small-scale detailed radiation intensities must also be known by civil defense personnel so that recovery operations can be started.

Rather than attempt to define parameters for a practical remote detector site it is more convenient and important to have an understanding of the effect of surface structures, vegetation and of other small-scale effects on a particular radiation measurement. The adaptation of perturbation effects to any particular situation depends upon the intended use of the data. If the data obtained in a particular area is to be used by personnel in that area only, no corrections to the data

should be made. However, when a measurement is made to obtain an over-all representative value of the radiation level, data corrections should be made if local terrain or other effects perturb the radiation field at that particular site. If an automatic network of detectors were to be used to obtain a gross representative picture of the radiation field, a study would be necessary to determine the optimium placement of detectors. When measurements are made with hand held survey meters or remote probe instruments to obtain both local and representative data, some perturbation corrections to the actual local reading may be necessary to obtain good representative data. In this section an estimate is presented of how the small-scale effects might change the radiation intensity at any given location.

B. GROUND ROUGHNESS

Ground roughness effects are variations in the radiation level above a contaminated field caused by relatively small crenulations in the surrounding terrain (i.e., deviations from an ideally smooth plane). The definition does not include terrain effects caused by nearby artificial or natural features which limit the field of contamination (i.e., deviations from an infinite plane). Examples of ground roughness variations include paved areas, deeply plowed fields, and turfed areas.

All earth surfaces are rough to some extent and vary only in their relative degree of roughness. If the same quantity of fallout were distributed on rough ground (such as a plowed field) as on a perfectly smooth plane, a lower radiation level would be expected at three feet above the rough ground. The reason for this is that part of the fallout material falls into the cracks or pockets and is partially shielded from the detector.

The reduction of radiation intensity caused by rough ground is not well known for different surfaces. Spencer[23] indicates a reduction of 0.55 for an open Nevada field without any indication of the degree of roughness. An early experiment[24] gave an estimated reduction of 0.77 for a nearly level, coarse gravel, desert surface relatively free of sagebrush. A later experiment[25] over "relatively" smooth desert terrain, indicated a reduction of 0.72. Preliminary results from another experiment[26] indicate an approximate reduction of 0.60 for a flat, dry, lake bed; 0.45 for a deeply plowed field (6-inch furrows every 30 inches); and 0.55 for "relatively" rough desert terrain. These values are in complete harmony with the estimated reduction factors given in the OCD Engineering Shielding Manual for various ground roughness conditions. The OCD estimated reduction factors are given in Table 3. The radiation intensity as modified by ground roughness, is approximately 0.50 to 0.80 of that expected from a smooth infinite plane.

TABLE 3. Estimated Reduction Factors for Various Ground Roughness Conditions

Terrain	Maximum Intensity Expected
Smooth plane	1.00
Paved areas	0.83
Lawns	0.77
Graveled areas	0.66
Ordinary plowed field	0.55
Deeply plowed field	0.47

C. FALLOUT DISTRIBUTION ON VEGETATION

In discussing open field radiation levels as affected by fallout distribution on vegetation, Spencer[23] says:

> "A question of particular importance relates to the amount of fallout material which may remain suspended above the earth in trees and shrubbery. This has not been accurately determined. There is evidence that not more than a few percent of the material descending, e.g., upon a tree will remain on the limbs and leaves of the tree if the surfaces are dry."

Experience in monitoring radiation levels above fallout-contaminated fields at the NTS has shown that fallout does not normally cling to trees and bushes in dry climates. No data or experience are available in areas of wet climate or high humidity.

In measuring radiation levels, the detector should not be placed directly under a tree or in a bush Even if only a small percentage of fallout remained on a tree or bush a high radiation reading might result if the detector were placed adjacent to the contaminated leaves. Conversely, if the detector is placed several feet away from trees or bushes with fallout on their leaves, this fallout would have very little effect on the radiation reading. Radiation contributions from fallout on a tree or on the ground under the tree will be approximately the same if the detector is several feet away.

D. TERRAIN EFFECTS

Open field radiation levels will be influenced by the existence and location of various terrain features such as curbs, embankments, cliffs, lakes, and all other features affecting the geometry of the terrain. Before specific terrain effects are discussed, it is helpful to understand the

relative contribution from fallout material deposited at various distances from a detector. Table 4 contains reduction factors due to limited circular areas of contamination. The detector is assumed to be a 3 ft above smooth ground and the gamma spectrum taken is that for fission products at about 1 hour after detonation. The value of these reduction factors is expected to be slightly higher when related to rough fields rather than to smooth planes. Figure 1 shows the dose rate 3 ft above the center of a Co^{60} contaminated circular area as a function of the circule radius. It is also of interest to estimate reduction factors above the center and edges of contaminated strips. These estimates are given in Table 5.

From these two tables, estimates can be made of terrain effects on the detector response. If a paved street if 100 ft wide, the radiation level above the center would be 63% of what it would be if the street were of infinite width. The level at the edge would be 38% assuming no contribution from beyond. The edge level would be about 60% of the center level. If the detector were 10 ft inside the edge of the street, its response would be 54% (17 + 37) of the infinite field dose rate or 85% of the center dose rate.

The presence of curbs, embankments, and cliffs would act as radiation shields to the detector. These could be treated as presenting limited strips of contamination to the detector and Tables 4 and 5 used to estimate their effect.

The existence of terrain features tends to lower the infinite smooth plane dose rate as would be measured by a detector 3 ft above the ground. The amount of reduction depends upon the size and location of these features. If detector positions are chosen based on a knowledge of these effects (Tables 4 and 5), reductions of not more than a few percent are expected. Again, if the detector positions are

TABLE 4. Fraction of Infinite Plane Dose Rate 3 Ft Above Contaminated Circular Areas

Radius of Circular Areas, ft	Fraction of Infinite Plane Dose Rate
0	0
10	0.22
20	0.33
30	0.40
50	0.50
70	0.56
100	0.63
150	0.71
200	0.76
300	0.82
500	0.89
∞	1.00

TABLE 5. Fraction of Infinite Plane Dose Rate 3 Ft Above Center and Edge of Contaminated Strip of Infinite Length

	Fraction	
Strip Width, ft	Above Center	Above Edge
0	0	0
10	0.22	0.17
20	0.33	0.23
30	0.40	0.27
50	0.50	0.32
70	0.56	0.35
100	0.63	0.38
150	0.71	0.41
200	0.76	0.43
300	0.82	0.46
500	0.89	0.48
∞	1.00	0.50

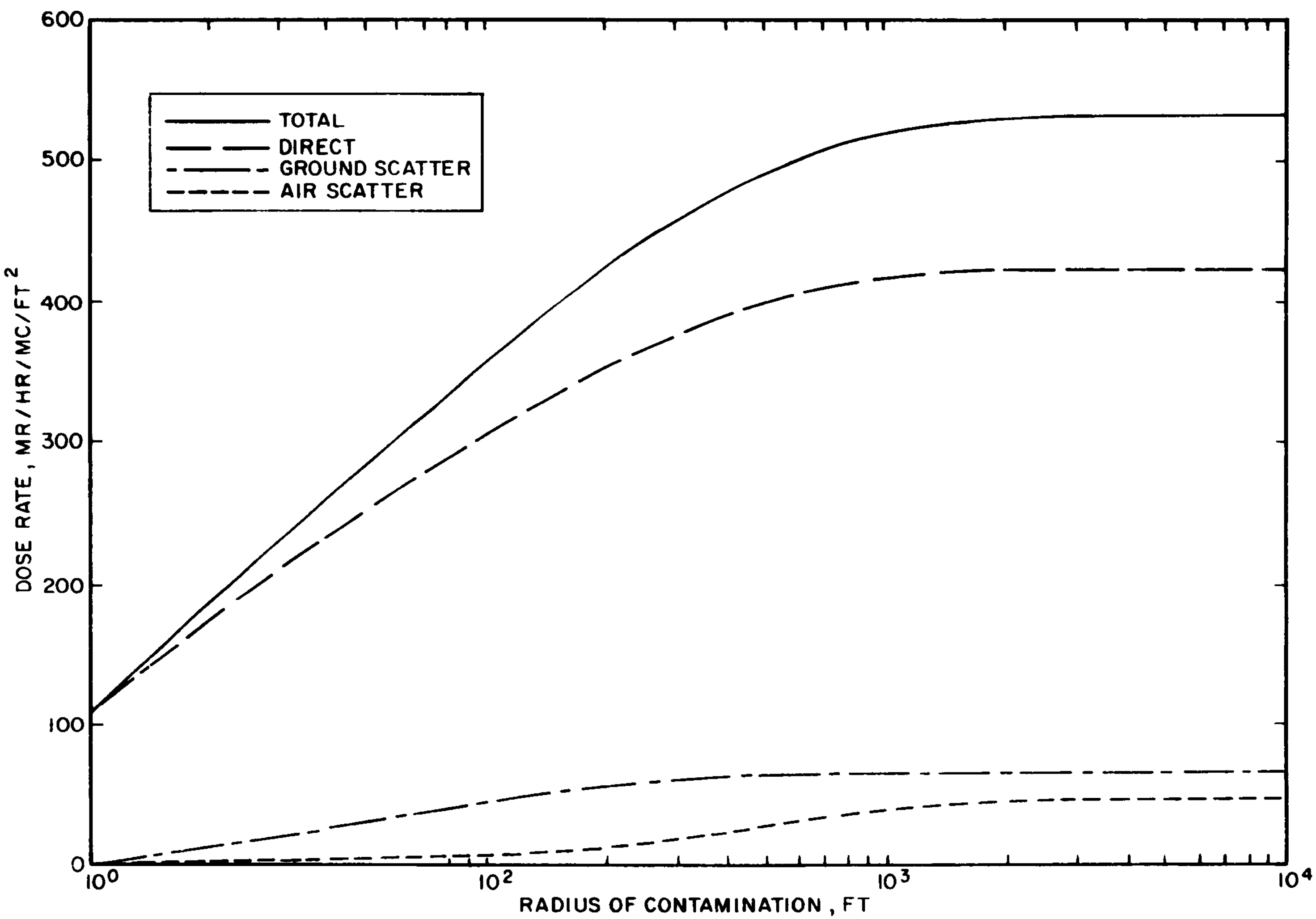

FIGURE 1. DOSE RATE 3 FEET ABOVE THE CENTER OF A Co-60 CONTAMINATED CIRCULAR AREA, NTS ALTITUDE

known in relation to terrain features, the amount of reduction can be estimated. It is worth noting that about 10% of the infinite plane dose rate is due to "skyshine" (radiation scattered by the air).

E. LOCAL SHIELDING BY STRUCTURES AND VEGETATION

There has been a considerable amount of work, both experimental and theoretical, in evaluating the shielding from fallout radiation provided by structures.[23,27] Most of this research has been concerned with locations inside structures. However, many of the same principles can apply to locations outside of structures. Attenuation of radiation provided by common materials such as earth, concrete, brick, and wood are well known and available in the literature.

The effect of structure location on the radiation level measured by a monitoring instrument will be discussed. The location of structures can be treated in much the same way as the location of terrain features. If the radiation level is measured in an alley between two large, high buildings 50 ft apart, the dose rate will be 50% of the infinite plane dose rate in the center and 32% at the edge. If the buildings are low (one story), a much higher dose rate would be expected. One should add 10% to account for skyshine. The contribution from contamination on the roofs of the structures should also be considered. This contribution will depend upon the heights of the buildings, the distance from the detector and intervening shielding material.[23,27]

If a detector were between two 8-inch concrete block fences 20 ft apart, it would read about 50% of the infinite plane level; 0.33 for a limited strip of contamination plus 0.10 for skyshine plus 0.06 for the contribution coming through the concrete walls. If the fences were wooden, the reading would be much higher because of a lower attenuation factor.

The shielding of a monitoring instrument by vegetation is also of interest. Consider a forest of 1-ft-diameter trees located 10-ft apart and fallout uniformly distributed on the ground. It is estimated that a detector would read from 50 to 70% of the open field dose rate, depending upon its location relative to the nearest tree.

There are innumerable examples that could be cited concerning the effects of location of structures and vegetation on the radiation level as read by a monitoring instrument. Shielding calculations and methods of handling these effects are well known.[23,27] It can be seen from the discussion that if reasonable care is taken in locating monitoring instruments in the open, a predictable reduction factor of a few percent can be achieved.

F. EFFECTS OF WEATHERING

As with other small-scale effects, there is only fragmentary data to indicate the effects of wind, rain, leaching into soil, and other weathering phenomena on the fallout radiation field. Dunning[28] reported on measurements made of the radiation intensities at Rongelap Atoll over a 2-year period following fallout contamination from a nuclear weapons test. Carl F. Miller states,[29]

> "Resurvey data from surface and underground shots in Operation Jangle, Nevada Test Site, after exposure to winter winds, snow and spring rain indicate no significant change other than that due to radioactive decay. Radiation measurements taken during operation Castle, Eniwetok Proving Grounds in 1954 on the islands of several atolls before and during heavy rains for several months show no decrease that could not be accounted for on a basis of radioactive decay. Dunning and Lapp erroneously attribute the rapid decrease in gamma radiation during the first year to a weathering factor of 0.4, due to the first heavy rains 10 to 20 days after the first detonation, apparently by a comparison with an inappropriate decay curve. This misinterpretation has also been noted by Knapp in discussions on this subject."

Other data,[30,31,32] also indicate weathering effects to be of relatively small magnitude, probably less than a factor of 2 for long periods of time combining all types of weathering effects. Knapp,[9] in summarizing results of various weathering studies, reports that the data indicate weathering will not make much difference for a year or so, and that for several years thereafter the dose rate would not be less than 70% of the infinite plane dose rate due to weathering.

G. SUMMARY

Data on the various small-scale effects is very scarce and does not completely cover all conditions. The five general types of small-scale effects and the range of probable reduction factors are:

1. Ground roughness - 0.50 to 0.80
2. Distribution on vegetation - 0.50 to 1.00 (This is avoidable.)
3. Geometry of terrain - 0.50 to 1.00 (This effect can be avoided or easily controlled.)
4. Local shielding - 0.35 to 1.00 (Easily avoided or controlled.)
5. Weathering - 0.70 to 1.00

In the case of radiation detector placement for civil defense monitoring items 2, 3, and 4 can be quite accurately predicted or avoided by logical placement of the detectors. The range of the unpredictable reduction factor due to the other two aspects of weathering is 0.35 to 0.80.

APPENDIX A
PRESENT CIVIL DEFENSE MONITORING OPERATIONS

A. INTRODUCTION

The purpose of this contract to augment present civil defense monitoring techniques could not be affected without examining and understanding the civil defense operations. An examination of the civil defense structure was made in which various locations and personnel on the state, local, and regional levels were visited to discuss the present operational philosophy and its associated problems. Some of the contacts made were: Mr. H. Stebbings, OCD Regional Office, Region 7, Santa Rosa, California; Mr. C. Rainey, Intelligence Coordinator, California Disaster Officer (CDO); Mr. E. Joyce, State Region 1, CDO; and Mrs. Jane North, Assistant Director of Operations and RADEF Chief, State Civil Defense, Phoenix, Arizona.

Although some of the details of the civil defense operations are constantly changing, the general concepts and procedures can be outlined in a general manner to comprehend more fully the present system and how it works. These procedures are described as it is supposed they will function in an emergency situation. The theoretical operation is presented and not the operational problems that may arise in the actual situation. These requirements for monitoring in civil defense operations are set down in OCD publications as Appendices 1, 2, and 9 to Part E, Chapter 5 of the Federal Civil Defense Guide. The state and local methods may vary in their fulfullment of these requirements.

B. OPERATIONAL TECHNIQUES

1. Monitoring Methods

a. Manned Portable Survey Meters

The most predominant monitoring method used in civil defense is monitoring with a manned portable survey meter. These meters are included in the CD V-777 radiological monitoring kit which the OCD makes available to states for further distribution to qualified sites. Each monitoring station must consist of at least two trained monitors and possess some method of communication, be it radio or telephone. The CD V-777 kit consists of two personnel dosimeters; (the V-730 and V-740 or V-742); one dosimeter charger (the V-750); and three survey meters (the V-700, V-710, or V-715, and the V-720 or V-717 remote). The monitors take their readings in the immediate area with the survey meters and report to the next echelon.

The fixed monitoring stations are deployed mainly in state and city agencies and form the backbone of the monitoring system. Examples of this are the city police and fire departments, sheriff's offices, highway patrol, or state police and division of highways. Although the emphasis lies in employing personnel from these various agencies, volunteers from any particular occupation are still trained and utilized.

Federal Guide, Part E, Chapter 5, Appendix 2, March 15, 1963, states the following procedures for a monitor in a fixed monitoring station:

"C. Fallout Monitoring Station Operations

(1) Flash Reports. Begin outside surface monitoring to determine the time of fallout arrival. When outside dose rate exceeds 0.5 r/hr make FLASH REPORT to the EOC using the following format: Example: This is Monitoring Station XYZ. Dose rate exceeded 0.5 r/hr at 1000 hours.

"(2) Monitoring Times and Reporting Schedule. All reports will utilize local time (Eastern Standard Time or Eastern Daylight Time) and will conform to the reporting schedule shown on the Radiological Reporting Log (See Handbook for Radiological Monitors, Appendix 9). Reporting times indicated on the Radiological Reporting Log will be converted to local time using the Time Conversion Chart on the reverse side of the log. These conversions will be entered in spaces provided above Greenwich Meridian Times of the log.

"(3) Dose Rate Reports. Except as provided in (5) below, the scheduled unsheltered dose rates will be measured and recorded. Upon call for report from the RADEF Officer the report will be rendered in the format as indicated below:

Example: This is Station XYZ. 2200 hour dose rate 57 r/hr.

"(4) Dose Measurement Report. The accumulated dose measurements will be reported as a part of, and immediately following, the 2200 hour (2300 hours daylight time) report using the below format:

Example: Measured dose at 2200 hours 720 roentgens.

"(5) Discontinuance of Unsheltered Monitoring. When the unsheltered dose rate reaches approximately, or exceeds 100 r/hr they will be calculated from sheltered dose rates. See paragraph 4.3, Handbook for Radiological Monitors.

"(6) Resumption of Outside Monitoring. Resume outside monitoring after the unsheltered dose rate has decreased to 25 r/hr."

b. Mobile Monitoring Techniques

Mobile monitoring provides for transporting radiological monitors with portable survey meters in automobiles

or light trucks to allow a greater area coverage. In some instances, the monitor may proceed on foot for a detailed survey of a local area. Area Monitoring is described in FG-E-5.9 as follows:

"Area monitoring is used to locate zones of contamination and determine the dose rates within these zones. The monitor should be informed by his radiological defense officer concerning routes to be followed, locations where readings are needed, the mission dose, and the estimated time needed to accomplish the mission.

"a. Plan to keep personal exposure doses as low as possible.

"(1) Know the specific accomplishment, extent, and importance of each monitoring mission.

"(2) Know the allowable exposure dose for each mission and the expected dose rates to be encountered.

"(3) Make allowances for the exposure to be received traveling to and from the monitoring area. Obtain information about the condition of roads, bridges, etc., that might interfere with the mission and lengthen exposure time.

"b. Clothing needed for the mission.

"(1) Tie pant cuffs over boots or leggings.

"(2) Wear a protective mask, gloves, head covering, and sufficient clothing to cover skin areas when dusty conditions prevail. If no masks are avilable, cover the nose and mouth with a handkerchief.

"c. Equipment needed for the mission.

"(1) Use the CD V-715. If the dose rates are expected to be below 50 mr/hr, also carry the CD V-700.

"(2) Wear a CD V-742.

"(3) Carry contamination signs, if areas are to be marked. This may also require stakes, heavy cord, hammer, and nails for posting the signs.

"(4) Carry a pencil, paper, and a map with monitoring points marked.

"d. Procedures for area monitoring are:

"(1) Zero the dosimeter before leaving the shelter and place it in a pocket to protect it from possible contamination.

"(2) Check the operability of the CD V-700 abd CD V-715, if it is to be used.

"(3) Use vehicles such as autos, trucks, bicycles, or motorcycles when distances are too great to cover quickly on foot. Keep auto and truck cab windows and vents closed when traveling under extremely dusty conditions. The use of a bicycle or motorcycle may be more practical if roadways are blocked.

"(4) Take readings at about three feet (belt high) above the ground. If readings are taken from a moving vehicle, the instrument should be positioned on the seat beside the driver. If readings are to be taken outside a vehicle, the monitor should move several feet away from the vehicle to take the reading.

"(5) Record the dose rate, the time and location for each reading. If readings are taken within a vehicle, this should be noted in the report.

"(6) Post markers, if required by the mission. The marker should face away from the restricted area. Write the date, time, and dose rate on the back of the marker.

"(7) Read the pocket dosimeter at frequency intervals to determine when return to shelter should begin. Allowances should be made for the dose to be received during return to the shelter.

"(8) Remove outer clothing on return to the shelter and check all personnel for contamination.

"(9) Decontaminate, if required.

"(10) Report results of the survey.

"(11) Record radiation exposure."

c. Aerial Monitoring Techniques

State or local civil defense officials can contact the Civil Air Patrol and make arrangements for organizing aerial monitoring teams to be used when necessary. Aerial monitoring capability is described in FG-E-5.1 as follows:

"Aerial monitoring capability should be developed at the approximately 3,000 public use airports that have servicing facilities. This will provide capability for the more thorough monitoring of the sparsely settled areas as well as capability for the rapid monitoring of transportation routes and essential areas and facilities that may not have a monitoring capability.

"The Civil Air Patrol has been authorized to assist State and local governments in aerial monitoring operations. Each of the 50 states has formalized a working agreement with the CAP Wing of its State. Further working agreements between CAP and CD organizations should be effected at county and local levels. Subsequently, the local RADEF officer should assist in working out the emergency operating procedures with local Civil Air Patrol Group or with other private pilots. Detailed guidance for planning and developing aerial monitoring capability is presented in Appendix 3."

APPENDIX B

AUTOMATIC RADIATION MONITORING SYSTEMS

A. Radiation Monitoring Over Long-Distance Telephone Lines and Direct Field Lines

The system for radiation monitoring over long-distance telephone lines and direct field lines[9] was developed for the remote monitoring of gamma radiation resulting from atomic explosions. The principal use of this system has been over long-distance telephone lines, but it is also used over direct field lines for monitoring sites within approximately 15 miles of the control station.

The control station operator obtains radiological data from detector stations located anywhere within the country. Except for the control station, the equipment is entirely battery operated and will operate unattended for long periods. The first version of this system was placed in operation during 1955 Nevada tests and a later version was in operation during the 1957 tests.

The complete system is composed of several radiation-monitoring stations and one or more control stations. The operating frequency which is a measure of the dose rate is 300 to 1400 cps and is read by a frequency counter and printer at the control station. The printer prints the frequency on a tape output which must be calibrated against voltage for each station. A calibration signal is generated at each station and applies a fixed voltage to the input of the control unit. Grounding the input gives the frequency characteristic of zero radiation intensity. The radiation intensity data are determined from the tape by comparing the readings with a calibration curve for the station.

The monitoring station consumes power only during interrogation which lasts for about 2 minutes. The stations used over long-distance telephone line circuits during the Nevada tests required few or no battery changes for the duration of the test. However, this was not the case for stations connected by direct field lines that were interrogated at very frequent intervals.

The control station consists of the radiation monitoring switchboard, readout equipment, and a telephone. To interrogate a field line station, the operator sets the route selector on "Field Line," depresses the field station switch corresponding to the desired station (A, B, C, etc.), and then depresses the "Field Call" key which connects a d-c voltage to the selected field line to interrogate the station.

In interrogating a station on a long-distance circuit, the control station operator switches the route selector and places a regular station-to-station, long-distance call to the station to be challenged. The station automatically answers and sends in its data.

The detectors are halogen-filled Geiger counters, Anton Types BS-212 and BS-1, with ranges of 10 to 20,000 mr/hr and 0.3 to 100 mr/hr, respectively. The electronic circuits used with both counters have a time constant of approximately 5 seconds.

B. A Radio Link Telemetry Radiation Monitoring System

A complete remote radiation telemetry system[10] consisting of a control console and ten rechargeable, battery-operated monitoring units for measuring radiation dose rates from 1 mr/hr to 500 r/hr has been field tested. The radio system of the radio-linked telemetry system has a range of 10 miles line-of-sight. The low power radiated by the information transmitter precludes any non-line-of-sight application, unless

at very close range. Active repeaters are used on the interrogation frequency. The following information describes the over-all radio system.

Interrogation System

Frequency of operation	150.33 Mc
Transmitted power	60 watts
Receiver sensitivity	1 microvolt (for dependable operation)
Modulation	FM/15 Mc deviation Motorola "Quick Call" modified

Telemetry/Information System

Frequency of operation	231.9 Mc
Transmitted power	4 watts
Receiver sensitivity	10 microvolts (for usable output)
Modulation	FM/7.5% deviation FM/FM standard telemetry-IRIG Channel 8.

The interrogation system is composed of a custom-packaged tone control receiver, a modified Motorola tone generator/timer unit, a standard Motorola 60-watt, FM transmitter, and an interrogation control panel.

The tone control receiver provides timing signals to users in areas not normally served by wire lines. These are rugged units and are designed to operate continuously in excess of 10 days on an internal battery pack. The unit provides relay closures which, when activated by a certain tone code, operate the function desired (e.g., equipment turn on, calibrate, readout, and equipment shutdown).

A modified Motorola tone generator/timer unit is used to generate the tone codes acted upon by the receiver. The 60-watt transmitter is a standard Motorola item.

The interrogation panel is a switch and relay complex which sets up the individual tone codes required for the various functions. It also acts as a system control and monitor panel.

The telemetry or information system is a standard FM/FM equipment layout minus a subcarrier discriminator. The system is composed of an FM transmitter, voltage-controlled oscillator, power supply, FM receiver, electronic counter, and digital recorder. The audio output of the FM receiver is fed directly to a counter and then to the recorder. The FM transmitter, voltage-controlled oscillator, and d-c power supply are standard Teledynamics, Inc., items. The FM receiver is a standard Nems-Clarke model covering the 175- to 280-Mc band. The receiver has been modified to use a carrier-operated relay, and features a constant audio output regardless of optional speaker volume setting. The electronic counter (Berkeley Instruments) measures the variable audio frequency from the receiver and passes it on to a digital recorder which prints out the frequency at a repetition rate convenient to the operator. The recorder is also made by Berkeley Instruments and is a companion unit. Detector units are located at remote locations at distances up to 10 miles and challenged to report dose rates to a readout system continually. Individual radiation dose rates are recorded for permanent reference.

Some disadvantages are the battery-operated units which may be called upon to operate in excess of 10 days and the line-of-sight communications with a range of only 10 miles. The last consideration is of importance where high-intensity radiation fields must be monitored from great distances.

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